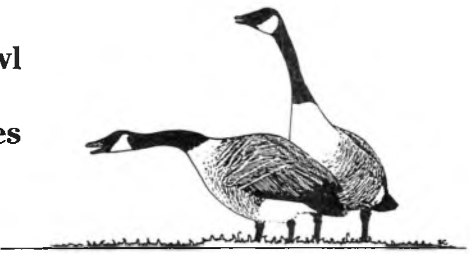
Crop damage, autumn waterfowl populations and cereal grain harvests in the prairie provinces of western Canada



ROBERT G. CLARK, HUGH BOYD and BERT POSTON

We examined annual variations in cereal grain production, harvest chronology and waterfowl populations for the period 1978-87 in western Canada, testing whether damage to wheat and barley crops was affected most by speed of harvest, crop area and yield, Mallard and goose population levels, or a combination of these factors. Levels of damage (numbers of bushels lost or total compensation payments) were unrelated to seeded areas and yields of wheat or barley. Correlations between estimates of goose or Mallard abundance and crop damage were weak, whereas those between damage and estimates of harvest delay were consistently much stronger. Numbers of feeding stations did not influence levels of crop damage recorded in Saskatchewan. Although cereal grain market value was associated with compensation paid to producers, the relationship differed from province to province.

Overall, multivariate analyses that considered statistically all variables revealed, simultaneously, that delay in harvest was the most important factor affecting damage to cereal crops. Our results, based on the most reliable data available, were consistent with earlier reports and should help to dispel the perception held by many agricultural producers that crop damage levels are related directly to the size of waterfowl populations.

Damage to cereal grain crops by fall-staging ducks has a long history in western Canada (Bossenmaier & Marshall 1958, Jakimchuk 1969, Sugden 1976, Boyd 1980) and United States (Knittle & Porter 1988). Substantial damage only began to be reported in the 1940s after most farmers adopted the practice of swathing (rather than straight-combining) crops. Grain is more vulnerable to damage when it has been cut and stacked in windrows to ripen. Thus, the length of time that the grain lies in swaths before being combined is potentially an important factor influencing amounts of damage.

MacLennan (1973) reported nonsignificant correlations between estimates of autumn Mallard *Anas platyrhynchos* populations and crop damage in Saskatchewan and evaluated the combined impact of autumn Mallard numbers and precipitation on crop damage levels using multiple regression analyses. These two variables accounted for more variation in crop damage than did either variable singly, but the relative importance of the individual variables was not established. In a comprehensive review, Sugden (1976:7) reported that damage in the three prairie provinces was greatest in years when harvest was delayed by prolonged periods of cool, wet weather and that its severity was unrelated to the size of duck populations.

In response to concerns of producers and, to a lesser extent, hunting groups and conservation organizations, integrated crop damage management involving prevention and compensation/insurance programs has been implemented across the prairies. In the 16 years from 1972 to 1987, the Canadian government allocated over $37 million to control programmes, or about 50% of total costs (Poston 1985, 1991). Preventative techniques such as the establishment of lure crops and feeding (bait) stations have been established in areas of chronic damage (Sugden 1976, Gollop 1988, Poston 1985). Before 1978, general crop insurance and compensation plans, designed to mitigate crop damage, varied by province and farmer participation was uneven. In 1978, new federal-provincial agreements led to the introduction of a standardized damage compensation programme in the three prairie provinces. Subsequently, participation in the programme rose primarily in Saskatchewan because of increased

Wildfowl 44 (1993): 121-132

awareness, increased payments and elimination of insurance premiums by producers.

Previous analyses of the relationships between crop damage, harvest chronology, weather conditions and waterfowl populations (e.g. MacLennan 1973, Sugden 1976) examined few variables that might influence damage. Most reported simple correlations. Prior to 1978, estimates of crop damage were reported inconsistently because of differences in provincial programmes.We have examined these relationships for all three provinces for the period 1978-87, testing whether crop damage was affected most by variations in harvest chronology, crop area and yield, Mallard and goose population levels, or a combination of these factors. To place these results in an historical context, we reviewed and reanalysed earlier information collected when numbers of wetlands and ducks were much greater than during the drought conditions that prevailed in the 1980s.

Methods

Estimates of grain availability and speed of harvest

Acreages and yields of wheat and barley were obtained from annual reports of federal and provincial agricultural agencies. Other crops grown in the prairies are eaten occasionally by waterfowl, but acreages are very small (Sugden 1976, Poston 1985).

Progress of harvest was determined from weekly (Saskatchewan and Manitoba) or semimonthly (Alberta) estimates of swathing and combining progress (Provincial Crop Reports). These reports provided dates that harvest was initiated, along with estimates of the percentage of each crop that has been swathed and combined. Reports usually included general assessments of weather conditions. Initiation and progress of harvest is determined by factors such as spring seeding conditions, summer weather conditions and fall precipitation. These measures can be used to calculate an index of harvest chronology. To standardize the method of data compilation, we used the following approaches and assumptions. First, for each year, crop and provincial crop district, we determined the (Julian) dates when swathing began, and when 25%, 50%, 75% and 100% of the crop was swathed. Likewise, we determined the dates when 25%, 50%, 75% and 100% of the crop was combined.

Occasionally, crop reports failed to provide information about harvest progress. When that was so, we assumed that (1) combining began when 50% of the crop was swathed, (2) in dry weather, harvest dates for different stages of swathing and combining were calculated from the midpoints between crop reports, (3) in wet weather, respective dates were calculated by adding three days to midpoints of crop reports and, (4) three and seven days were added to the crop report dates during dry and wet falls, respectively, when harvest extended beyond the last crop report.

We mathematically "weighted" harvest progress dates by the area seeded to wheat and barley in each crop district to derive a weighted average harvest chronology for each province for the period 1978-87 (Fig. 1). *Harvest delay* was then calculated by summing deviations from the mean dates for each stage of harvest; the sum of the deviations was negative when harvest was rapid. *Harvest synchrony* was calculated by summing the difference between weighted dates of swathing and combining for each stage of harvest; the sum of the differences was small when synchrony was high, signifying a rapid harvest. *Span* of harvest was the deviation from the 10-year mean of the number of days between dates when swathing began and combining ended.

Estimates of crop damage

The actual amount of grain consumed or wasted by waterfowl remains unknown. Estimates are largely based on "reported losses" submitted by landowners claiming remuneration. Additional "unreported losses" undoubtedly occur but are difficult to estimate. The reporting rate is probably affected by many factors. These include such things as the extent of damage (e.g. light damage may be missed more easily), landowners' past experience with damage and claiming procedures, farm profitability and market prices, tolerance of damage which may be linked to income, convenience of reporting, awareness of services and available money, particularly in crop damage programme areas, and, possibly, attitudes and decisions of neighbouring farmers.

In 1978, a standard, prairie-wide compensation programme was implemented in the

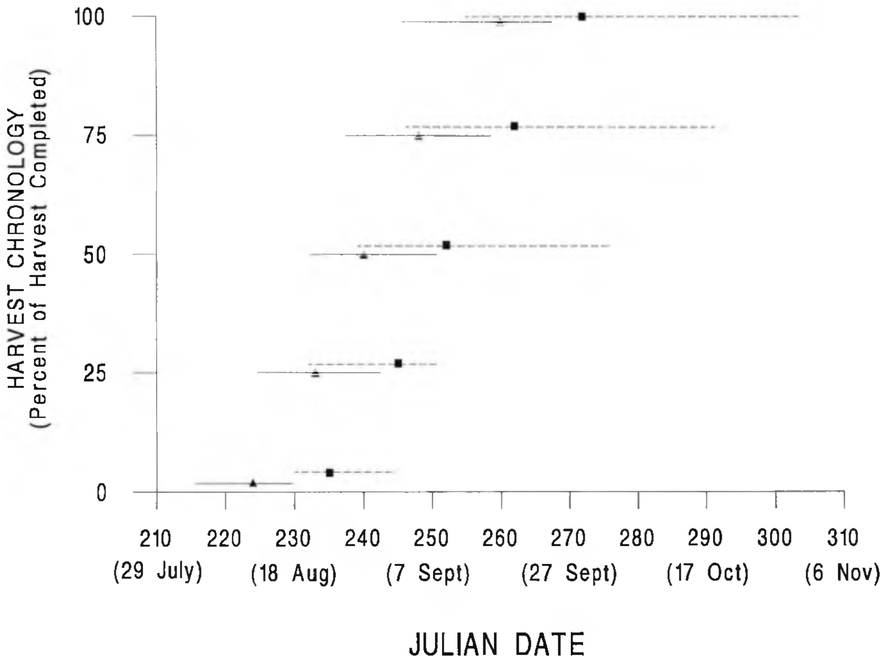


Figure 1. Patterns of harvest chronology for barley in Saskatchewan, 1978-87. Shown are the mean and range of dates of swathing (closed triangles with solid line) and combining (closed squares with broken line) for different stages of harvest (y-axis).

prairies. From 1978 on, estimates of crop damage better reflected actual levels, and facilitated more reliable comparisons of damage among years and provinces than had previously been possible. When a crop damage claim is filed, an insurance adjuster visits the field(s) to assess damage level(s) which, in turn, can be converted to estimates of bushel and dollar losses. These estimates should probably be considered in relative rather than absolute terms because of variations in estimates among adjusters.

Although we examined the relationships among several explanatory variables and the value ($) of grain lost to waterfowl, comparisons with the amount (bushels) of grain lost are probably most meaningful. That is because, unlike the quantity of grain lost to waterfowl, the value of grain varies annually in relation to changing market conditions as well as growing conditions, and it also declines when grain lies unharvested during wet weather.

Estimates of the size of the fall flight of Mallard

The Mallard is the principal duck species that feeds in grain fields (Bossenmaier & Marshall 1958, Sugden 1976). Annual indices of Mallard numbers in September were calculated by using the numbers of adults estimated to have been present in May, from the aerial surveys carried out by the USFWS, corrected for visibility by ground surveys carried out by CWS. We used the estimates for the southern parts of Alberta, Saskatchewan and Manitoba, supplemented by the estimated numbers in (1) the Mackenzie valley and northern Alberta, allocated as 1/2 to Alberta and 1/4 to Saskatchewan (with the remaining 1/4 assumed to go to British Columbia) and, (2) numbers in northern Saskatchewan and Manitoba, allocated as 1/3 to Saskatchewan and 1/3 to Manitoba (with 1/3 to Ontario). Adult deaths from May to September were ignored because nothing is known about their variations from year to year. Adult totals were then augmented by estimates of the numbers of young Mallard.

This was done by multiplying the adult totals by the provincial estimate of the ratio of hatching year birds/adults in the Canadian Wildlife Service's annual National Harvest Species Composition Survey (NHS). These indices are generous because no adjustment was made for the greater vulnerability to hunting of juvenile ducks.

Estimates of the relative abundance of geese

Because no direct estimates of the total numbers of geese in the prairie provinces during the cereal harvest period were made in the years 1978-87, an index was derived from NHS data, expressed as the mean number of geese shot by a successful hunter in a province. This allows for annual variations in the number of hunters, many of whom turned from ducks to geese as ducks became scarce. Hunter success usually is greater when young geese make up a larger proportion of the population after a favourable summer, increasing the size of the fall flight. Because the reported kill has not fully kept pace with the large increases in the numbers of geese breeding in the central Canadian arctic in the last 30 years, this index is conservative.

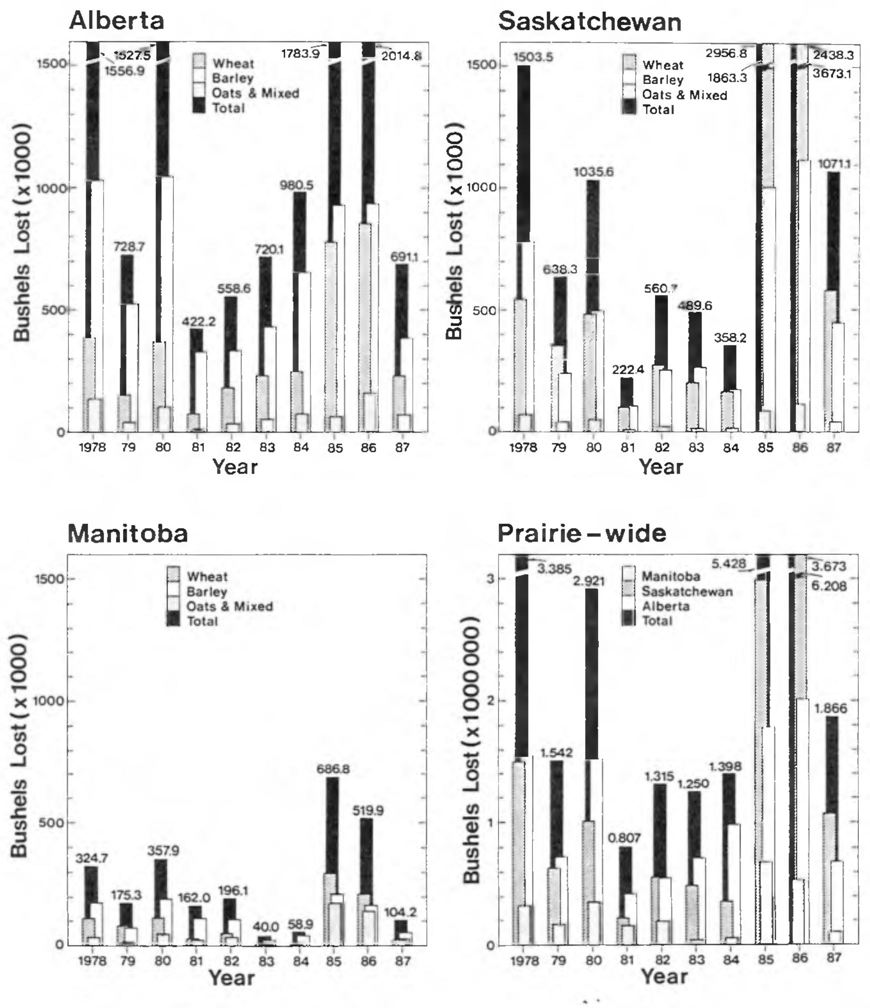


Figure 2. Annual estimates of crop damage for the prairie provinces, 1978-87 (from Poston 1991).

Statistical analysis

Initially, we used correlation analysis to examine relationships among estimates of harvest chronology (delay and synchrony), crop area and yield, fall flight and crop damage. Analyses were conducted separately for each province because of large differences in crop acreages and size of waterfowl fall flights. We used provincial-level data for crop area, yield and harvest information to maintain a consistent spatial scale with fall flight and crop damage estimates.

Stepwise regression then was used to determine the relative importance of explanatory variables (crop area and yield, fall flight, harvest chronology) affecting variation in crop damage, with significance set at 0.10 because of low test power (i.e. n = 10 for each province). Partial F was used to determine the relative importance of each explanatory variable (in a final model) when the stepwise procedure was completed. We report the sign of the regression coefficients, but do not interpret their magnitudes because units of measurement varied widely among explanatory variables and we did not intend to develop models to predict crop damage. In any case, forecasting crop damage is a dubious exercise because it is not possible to predict autumn precipitation with any certainty. Statistical tests described by Zar (1984) were executed on the Statistical Analysis System (SAS Inst. 1990) with significance set at 0.05 unless indicated otherwise.

Results and discussion

Crop area, yield and crop damage

Across the prairies, levels of crop damage (Fig. 2) were unrelated to seeded areas and yields of barley or wheat (Table 1). Weak positive correlations were found between yield and damage to crops grown in Saskatchewan, suggesting that damage may have been higher in years with higher yields, possibly because of the relationship between these two factors and rainfall (further details below), or because farmers were more likely to file damage claims when yields were high. On the other hand, similar results were not obtained for Alberta or Manitoba.

Speed of harvest and crop damage

We found moderate to strong positive correlations between damage levels and estimates of harvest delay, harvest synchrony and span of harvest for both barley and wheat (Table 2). Correlations were stronger in Saskatchewan and Manitoba than in Alberta, possibly because harvest reports for these provinces were provided each week rather than semimonthly (Alberta), enabling us to calculate more representative estimates of speed of harvest. This problem was most apparent when estimating harvest synchrony for Alberta. Correlations with swathing delays were usually less than for combining or harvest delays, although variables were intercorrelated (Table 3). If swathing is delayed, grain remains standing and cannot be eaten by waterfowl. However, a delay in combining the cut grain increases its vulnerability to damage by birds.

Mallard fall flight estimates, indices of goose abundance and crop damage

Overall, correlations between estimates of goose or Mallard abundance and crop damage were weak (Table 4). In Alberta, a moderate correlation was found between bushels of barley lost and Mallard fall flight. Correlations obtained for duck numbers in Manitoba, though nonsignificant, were negative. We have no explanation for this, but speculate that local Mallard numbers may have no rela-

Table 1. Spearman rank correlation coefficients for the association between levels of damage (bushels and dollars) to barley and wheat crops, and estimates of crop acreage and yield.

	Alberta		Saskatchewan		Manitoba	
Variable	Bushels	Dollars	Bushels	Dollars	Bushels	Dollars
BARLEY						
Acreage	-0.503	-0.491	0.164	0.030	0.347	0.353
Yield	-0.109	-0.377	0.588[a]	0.515	0.200	0.152
WHEAT						
Acreage	0.273	0.297	0.103	-0.055	-0.018	-0.115
Yield	-0.055	-0.079	0.406	0.236	0.261	0.176

[a]P<0.10, with n = 10 for all correlations.

Table 2. Spearman rank correlation coefficients for the association between levels of damage (bushels and dollars) to barley and wheat crops, and estimates of harvest delay and synchrony.

	Alberta		Saskatchewan		Manitoba	
Variable	Bushels	Dollars	Bushels	Dollars	Bushels	Dollars
BARLEY						
Delay in:						
Swathing	0.683*	0.445	0.371	0.486	0.770**	0.709*
Combining	0.661*	0.557^{a}	0.770**	0.697*	0.863**	0.760**
Harvest	0.742*	0.523	0.760**	0.742*	0.830**	0.758**
Span	0.673*	0.685*	0.845**	0.839**	0.888***	0.839**
Synchrony	0.321	0.418	0.833**	0.845**	0.721*	0.661*
WHEAT						
Delay in:						
Swathing	0.830**	0.661*	0.333	0.552^{a}	0.867**	0.903***
Combining	0.820**	0.734*	0.879***	0.891***	0.900***	0.875***
Harvest	0.879***	0.782**	0.782**	0.903***	0.903***	0.915***
Span	0.790**	0.802**	0.857**	0.954***	0.945***	0.921***
Synchrony	0.406	0.515	0.778**	0.900***	0.835**	0.835**

^{a}, *, ** and *** refer to $P<0.10$, 0.05, 0.01 and 0.001, respectively, with $n = 10$ for all correlations.

Table 3. Spearman rank correlation coefficients (barley, wheat) for the associations among estimates of harvest delay and harvest synchrony (n = 10 for each provincial crop, where coefficients >0.63 are significant at P = 0.05).

Harvest estimate	Combining delay	Harvest delay	Span of harvest	Harvest synchrony
Alberta:				
Swathing delay	0.90,0.84	0.98,0.92	0.74,0.76	0.48,0.48
Combining delay		0.94,0.94	0.94,0.92	0.70,0.67
Harvest delay			0.81,0.84	0.53,0.56
Span of harvest				0.84,0.72
Saskatchewan:				
Swathing delay	0.32,0.88	0.64,0.94	0.71,0.88	0.48,0.69
Combining delay		0.92,0.95	0.86,0.97	0.87,0.83
Harvest delay			0.96,0.96	0.85,0.80
Span of harvest				0.91,0.83
Manitoba:				
Swathing delay	0.81,0.88	0.94,0.94	0.72,0.88	0.21,0.69
Combining delay		0.94,0.95	0.92,0.97	0.58,0.83
Harvest delay			0.86,0.96	0.39,0.80
Span of harvest				0.58,0.83

Table 4. Spearman rank correlation coefficients for the association between levels of damage (bushels and dollars) to barley and wheat crops, indices of goose and duck numbers, and an estimate of the proportion of young Mallard in the population (Hym).

	Alberta		Saskatchewan		Manitoba	
Variable	Bushels	Dollars	Bushels	Dollars	Bushels	Dollars
BARLEY						
Geese	-0.418	-0.358	0.006	-0.042	-0.285	-0.321
Ducks	0.564^{a}	0.382	0.321	0.285	-0.236	-0.309
Hym	0.576^{a}	0.382	0.430	0.236	-0.745*	-0.709*
WHEAT						
Geese	0.006	-0.127	-0.091	-0.224	-0.127	-0.164
Ducks	0.406	0.418	0.345	0.406	-0.176	-0.152
Hym	0.685^{a}	0.588^{a}	0.600^{a}	0.515	-0.673*	-0.685^{a}

^{a}, *, ** and *** refer to $P<0.10$, 0.05, 0.01 and 0.001, respectively, with $n = 10$ for all correlations.

tionship with crop damage because of postbreeding movements by much larger numbers of Mallards from other areas and provinces into the agricultural areas of Manitoba (Gollop 1965, Gilmer *et al.* 1977, Kirby *et al.* 1989). Similarly, correlations with geese were usually negative, possibly because years of cool, wet summer and autumn weather in the prairies (when crop damage escalates) are associated with poor breeding conditions for arctic-nesting geese (e.g. Boyd *et al.* 1982:16-17).

In years with delayed harvest in Saskatchewan (e.g. 1978, 1985 and 1986), damage not only intensifies in traditional areas but in areas not usually damaged (Mike Gollop, Saskatchewan Dept. Renewable Resources, pers. comm.). This arises for two reasons. First, more grain is lost to species such as Snow Geese *Anser caerulescens* and Sandhill Cranes *Grus canadensis* that normally are not associated with crop damage. Second, swathed grain in areas outside traditional crop damage areas is eaten by ducks as they migrate southward from the parklands where damage typically occurs.

Feed (bait) stations and damage compensation

Feed or bait stations have been used in Alberta and Saskatchewan to reduce crop depredation (e.g. see Poston 1991); Manitoba has few feeding stations. Stations are active in late summer until about 70-80% of surrounding commercial crops have been harvested, the period being longer when harvest is prolonged by wet weather. From 1978-87, about 25 stations were operated in Alberta, with very little annual variation. Thus, in Alberta, associations among damage estimates, waterfowl populations and harvest variables would not have been influenced by feed stations (i.e. the number of stations and mode of operation were constant during this period).

In Saskatchewan, the number of stations increased from 1978, when no stations existed, to 23 in the mid-1980s (median = 14 stations annually). Therefore, we examined associations between number of stations and crop damage estimates to test whether the number of feeding stations and crop damage levels were negatively correlated. The four correlations with damage to wheat and barley were nonsignificant and positive (r_s, range = 0.12 to 0.33, $Ps>0.35$). Furthermore, after controlling for harvest chronology and other variables (below), the number of feeding stations was not related to crop damage levels. These results do not imply that feeding stations are ineffective. Rather, the results indicate that feeding stations have little impact on the province-wide relationships between numbers of waterfowl, harvest chronology

Table 5. Relationships between damage to barley crops and estimates of crop acreages and yields, Mallard and goose numbers, and harvest chronology from stepwise multiple regression. Only significant (P<0.10) explanatory variables are shown, with respective partial-F values and sign (+ or -) of the regression coefficients. Coefficients of determination (R^2) shown in parentheses with the final regression model.

Damage	Explanatory variables	Alberta	Province Saskatchewan	Manitoba
BUSHELS	Combining delay	+36.5***		
	Span of harvest		+61.8***	+40.5***
	Final model	36.5***(0.82)	61.8***(0.87)	40.5***(0.81)
DOLLARS	Combining delay	+4.3a		
	Harvest delay		-4.0a	
	Span of harvest		+95.7***	+13.1**
	Final model	4.3a(0.35)	67.9***(0.95)	13.1**(0.62)

a, ** and *** refer to $P<0.10$, 0.01 and 0.001, respectively.

Table 6. Relationships between damage to wheat crops and estimates of crop acreage and yield, Mallard and goose numbers, and harvest chronology from stepwise multiple regression. Only significant (P<0.10) explanatory variables are shown, with respective partial-F values and sign (+ or -) of the regression coefficients. Coefficient of determination (R^2) shown in parentheses with the final regression model.

Damage	Explanatory variables	Alberta	Province Saskatchewan	Manitoba
BUSHELS	Area	+5.0a	+8.0*	
	Span of harvest	+19.2**	+30.4***	+69.6***
	Number of geese			+7.5*
	Final model	16.8**(0.83)	32.6***(0.90)	66.8***(0.95)
DOLLARS	Area	+5.2a	+9.1*	
	Swathing delay		-5.2a	
	Combining delay	+22.3**		
	Harvest delay		+4.3a	+74.1***
	Span of harvest		+89.5***	
	Number of ducks			-5.7*
	Final model	19.6**(0.85)	121.0***(0.99)	61.5***(0.95)

a, *, ** and *** refer to $P<0.10$, 0.05, 0.01, 0.001, respectively.

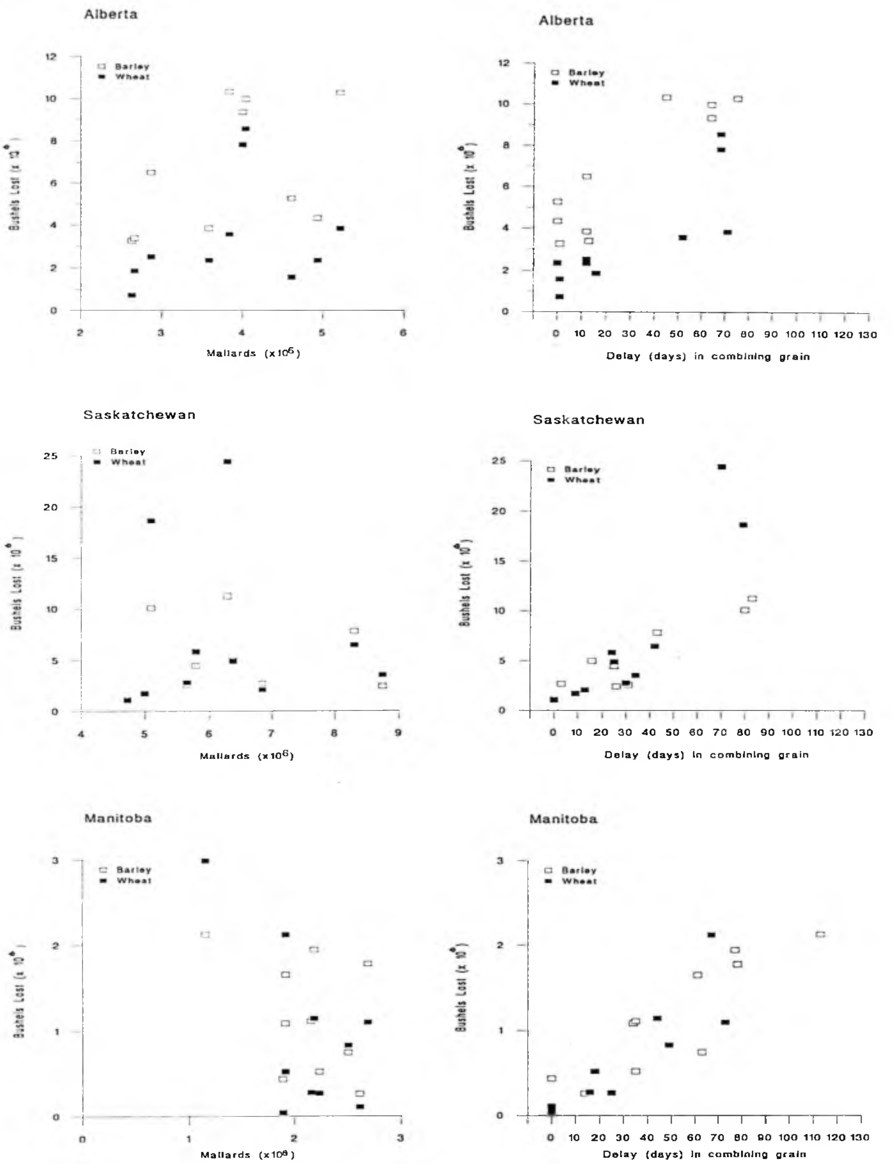


Figure 3. Relationships of crop damage with estimates of Mallard fall flight and delay in combining grain shown for barley (open symbols) and wheat (closed symbols). Delay in combining grain is expressed in relation to the average delay observed for the period 1978-87 such that zero values refer to the most rapid harvests. Correlation coefficients for these associations are shown in Tables 4 and 2 for Mallard numbers and delay in combining grain, respectively.

and crop damage. The last interpretation is supported by MacLennan (1973) who reported relationships similar to those found in our investigation *before* feeding stations were implemented in Saskatchewan.

Feeding stations attract large numbers of Mallards (e.g. Gollop 1988), possibly leading to traditional use of these sites by the same individuals. Thus, in years with poor production of young, adults may congregate earlier at feeding stations, whereas, in years with good production, young ducks may remain dispersed until later in the autumn. Although these assumptions have not been evaluated adequately, if they are correct, damage could be greater in years with higher production of young (Bruce Turner, Canadian Wildlife Service, pers. comm.). To test this, we correlated damage estimates with the proportion of young Mallard reported in the NHS. In general, correlations between damage and the proportion of young were greater than those for duck numbers, suggesting that damage was greater in years with greater numbers of young (Table 4). However, more young birds may have fledged (and were subsequently shot) in years with wet weather when crop damage was also greater. The last explanation is more plausible because multivariate analyses indicated that delay in harvesting grain was a better determinant of crop damage than the index of Mallard production (next section).

Multivariate analyses

We used stepwise regression to determine simultaneously the relative importance of different variables (Tables 1, 2 and 4) that might influence crop damage. With barley, delay in combining and span of harvest were the only variables that could account for substantial variations in crop damage levels (Table 5), particularly the number of bushels of barley lost to birds. With wheat, similar results were obtained (Table 6), except that damage increased when larger crop areas were sown in Alberta and Saskatchewan. This likely did not result from decreased acreage of barley (producing greater damage to wheat) because areas of these two crops were not negatively correlated (Alberta, r_s = 0.12; Saskatchewan, r_s = 0.39). Furthermore, when seeded areas expanded, span of harvest did not increase with either crop in any province (range, r_s = -0.13 to 0.09).

Indices of waterfowl abundance did not account for crop damage patterns, although in Manitoba there was a weak positive association between bushels of wheat lost to birds and our index of goose abundance (Table 6). The proportion of young ducks in the harvest was also unimportant. Overall, strongest relationships were found with harvest variables (Fig. 3).

Historical information

On a local scale, Jakimchuk (1969) reported that distance to (medium size) wetlands, number of neighbouring wetlands and precipitation were important determinants of local damage levels in Alberta, but he did not assess the relative impact of duck population size. Correlations were generally low (r<0.07) for 12 variables examined, and were <0.02 for precipitation during the week in which damage claims were made. Jakimchuk's results are perhaps surprising when compared with our findings and other analyses outlined below.

One criticism of our analyses might be that data were collected when Mallard numbers were relatively low, possibly masking influences of high duck numbers on crop damage. To examine this, we reviewed results of two other studies which analysed data obtained before 1979, during periods when Mallard populations were occasionally much higher than in the 1980s.

For the period 1956-68 in Saskatchewan, MacLennan (1973) found that fall precipitation explained 51% and 49% of variation in the percentage of crop damage policies claimed and average value per claim, respectively; corresponding values for correlations with fall Mallard populations were 10% and 8% (Table 7). The correlations with precipitation were significant whereas those with Mallard numbers were not (note that MacLennan did not report levels of significance). When precipitation and Mallard numbers were combined in a multiple regression (Table 7), coefficients of determination (R^2) were 60% with policy claims and 56% with average claim value, representing about 9 and 7% improvements in R^2s above those obtained with precipitation alone.

For the period 1964-1978, Hugh Boyd (unpubl. data) found that annual estimates of Mallards in August (an index of fall population size) and crop damage were not related (Table 8). Indeed, correlations were negative rather than positive. Results of these studies show that, for earlier decades and different areas, Mallard numbers and crop damage are not positively correlated.

General discussion

Using the most reliable data available, at a large spatial scale, our analyses indicate a

Table 7. Relationships between fall precipitation, estimates of Mallard fall flight and crop damage for the period of 1956-68, in Saskatchewan (MacLennan 1973). Shown are simple (*r*) and multiple (*R*) correlation coefficients.

Correlation with	Crop damage variable	
	Policies claimed (%)	Average payment/claim
Precipitation (*r*)	0.716*	0.699*
Mallards (*r*)	0.320	0.287
Precipitation and Mallards (*R*)	0.773	0.746

*$P<0.05$, n = 13 (years).

Table 8. Correlation coefficients between measures of crop damage by waterfowl, and estimated Mallard fall flight for three prairie provinces, 1964-78 (Boyd, unpubl. data). Also shown is number of years (*n*) for which data were available.

Crop damage	Alberta	Saskatchewan	Manitoba
Area damaged	-0.477*	-0.895*	-0.322
Bushels spoiled	-0.411	-0.924*	-0.322
n	14	7	6

*$P<0.05$.

weak relationship between estimates of waterfowl numbers and crop damage. Of the many variables considered that might influence crop damage, the most influential factor was harvest delay. Predictably, delay in combining grain was most important.

Multivariate analyses also failed to provide evidence that the abundance of Mallards or geese contributed substantially to the magnitude of crop damage, after accounting for the effects of harvest chronology. It seems reasonable to expect that amounts of grain lost to waterfowl during wet years would be greater when populations are large than when populations are low, but our analyses and those of MacLennan (1973) failed to find evidence for this idea. MacLennan (1973:30) argued that estimates of the abundance of Mallards are unreliable. However, in our study, even rank correlations fail to indicate trends with crop damage estimates. This is in striking contrast to relationships found with estimates of harvest chronology which were also rather crude, especially those calculated for Alberta. Nonetheless, current studies conducted at a smaller spatial scale (e.g. A. Arsenault, Saskatchewan Dept. Renewable Resources, unpubl. data) would help to resolve this uncertainty because estimates of local waterfowl numbers may be made more reliably.

Alternatively, perhaps the amount of grain lost does not increase substantially in years with large fall populations (with different delays in harvest) because (i) flock foraging intensity, hence efficiency, increases (i.e. birds recover grain from the swath or ground that was already shattered from heads; e.g. Clark *et al.* 1986), (ii) birds migrate from the prairies according to an unvarying schedule so that, regardless of population size, relatively few ducks and geese are still present in the prairies late in autumn during years with late harvest or, (iii) regardless of wet weather, some fields are harvested, many of these fields are attractive to foraging ducks (i.e. they contain much waste grain), and therefore the number of alternate feeding fields increases throughout the fall. At present, we are unable to determine which explanation is most tenable. If any (all) of these reasons hold, however, then incremental damage would diminish with increasing fall population sizes.

Although we examined several environmental or biological variables that determine the extent of crop damage, economic conditions could influence farmers' decisions to file a damage claim. For instance, market prices for wheat and barley varied as much as 2-fold from 1978 to 1987. Patterns of damage compensation across provinces were reasonably consistent and, in some cases, associated with grain prices. With barley, there was no correlation between market price and reported grain losses (r_s = 0.079, -0.356 and -0.188, for Alberta, Saskatchewan and Manitoba, respectively; Ps>0.31). However, wheat market price and grain losses were correlated negatively in Alberta (r_s = -0.624, P = 0.05) and in Saskatchewan (r_s = -0.588, P<0.10); no correlation was found in Manitoba (r_s = -0.188, P>0.60). Total compensation payments tended to rise when wheat prices were low. When we considered simultaneously the effects of harvest chronology and market prices on grain losses, we found that measures of speed of harvest explained a greater proportion of variation in grain losses than market price in six stepwise regressions (i.e. three provinces and two grain crops). Nonetheless, in these analyses, the amount of barley lost to ducks in Alberta rose ($P = 0.05$) with improving market prices whereas in Saskatchewan losses of barley ($P = 0.09$) and wheat ($P = 0.008$) rose when prices declined. In short, a delay in harvesting crops remained the most consistent and important variable affecting crop damage levels, but economic forces appeared to be of equal or greater significance than waterfowl populations or crop characteristics with respect to damage claims made by producers.

Additionally, our results have broader geographical and biological significance. For instance, in Argentina and Uruguay, damage to commercial cereal grains, rice, maize, sorghum and sunflower by Eared Doves *Zenaida auriculata*, Monk Parakeet *Myopsitta monachus* or ducks (e.g. whistling ducks *Dendrocygna bicolor* and *D. viduata*) appears to be closely linked with harvest practices and chronology (Maria-Elena Zaccagnini, INTA, Parana, Argentina, pers. comm., Weller 1969, Clark 1992). When inclement weather prolongs seeding and harvesting operations, ripened crops are vulnerable to damage by different bird species for extended periods. In these countries, as in Canada, conflicts between birds and agricultural producers might therefore be reduced by encouraging, or assisting, producers in damage prone areas to adopt farming practices that speed harvest.

Although results contained in this report show clearly that Mallard numbers and crop damage are not closely linked, crop damage compensation and prevention programmes must remain a crucial component of waterfowl conservation initiatives (e.g. Poston 1991). In western Canada, most ducks are produced on privately owned farmland. To implement conservation programmes, it is imperative to address the concerns of farming communities. For instance, to conserve large wetlands, prevention programmes are needed to mitigate damage. These programmes must also be cost-effective to remain economically and thus politically viable. In this regard, localized studies (i.e. small spatial scale) of waterfowl damage to agricultural crops are needed to determine whether, and to what extent, geographic scale influences the prairie-wide relationships that we examined.

Many farmers could reduce problems of delayed harvest (leading to reduced crop value) and subsequent bird damage, by cutting and harvesting standing grain in one operation (straight combining) and then drying the grain (see Sugden *et al.* 1988). For instance, where straight combining is typically employed (e.g. the UK), ripened cereal crops are not eaten by ducks (Thomas 1981). In areas of Canada that receive severe annual damage, a cost-benefit evaluation of this technique would indicate whether it is a viable alternative to compensation; unlike the last option, it represents a long-term *solution* to bird damage problems. Our study was not intended to direct changes in crop damage management programmes; rather, our results should help waterfowl conservation agencies to convince grain producers that more ducks do not translate directly into higher crop damage.

We are grateful to Barb Hanbidge who compiled harvest statistics and other data, to Garry Bogdan for discussions about the merits of straight-combining grain, to Bruce Turner for ideas about duck dispersion patterns, feeding stations and crop damage, and to John Trevor who drafted the illustrations. M.A. Gollop, A.A. Arsenault and an anonymous reader reviewed the paper, and provided many helpful comments. We thank provincial agencies for supplying agricultural information.

References

Bossenmaier, E.F. & Marshall, W.H. 1958. Field-feeding by waterfowl in southwestern Manitoba. *Wildl. Monogr.* 1:1-32.

Boyd, H. 1980. Waterfowl crop damage prevention and compensation programmes in the Canadian Prairie Provinces. Pp. 20-27 in: *Bird problems in agriculture* (E.W. Wright, I.R. Inglis and C.J. Feare, Eds.). Brit. Crop Protec. Council Monogr. 23.

Boyd, H., Smith, G.E.J. & Cooch, F.G. 1982. The Lesser Snow Geese of the eastern Canadian Arctic. *Can. Wildl. Serv., Occas. Paper No. 46.*

Clark, R.G. 1992. Bird pests in Uruguay and Argentina: biological control - habitat management. Unpubl. Report to United Nations (Project TCP/RLA/8965), Food & Agriculture Organization, Rome.

Clark, R.G. Greenwood, H. & Sugden, L.G. 1986. Estimation of grain wasted by field-feeding ducks in Saskatchewan. *J. Wildl. Manage.* 50:184-189.

Gilmer, D.S., Kirby, R.E., Ball, I.J. & Riechmann, J.H. 1977. Post-breeding activities of Mallards and Wood Ducks in North-central Minnesota. *J. Wildl. Manage.* 41:345-359.

Gollop, J.B. 1965. Dispersal and annual survival of the Mallard (Anas platyrhynchos). Ph.D. Thesis, Univ. Saskatchewan, Saskatoon.

Gollop, M.A. 1988. Impact of damage prevention sites on waterfowl resource users. Saskatchewan Parks, Recreation & Culture, Wildlife Branch. *Wildl. Tech. Rep. 87-7,* Regina.

Jakimchuk, R.D. 1969. A study of waterfowl damage to commercial grain crops in Alberta. Renewable Resources Consulting Services. Unpubl. Report to Alberta Dept. Lands and Forests, Edmonton.

Kirby, R.E., Cowardin, L.M. & Tester, J.R. 1989. Premigrational movements and behavior of young Mallards and Wood Ducks in North-central Minnesota. *U.S.D.I., Fish & Wildl. Serv., Fish & Wildl. Res. No. 5.*

Knittle, C.E. & Porter, R.D. 1988. Waterfowl damage and control methods in ripening grain: an overview. *U.S. Dep. Int., Fish Wildl. Serv., Fish Wildl. Tech. Rep. 14.* Washington, D.C.

MacLennan, R. 1973. A study of waterfowl crop depredation in Saskatchewan. Saskatchewan Dept. Renewable Resources, Fish Wildl. Branch, Regina.

Poston, B. 1985. A review emphasizing federal involvement in alleviating waterfowl damage to cereal grains on the Canadian prairies, 1972 to 1981. Can. Wildl. Serv. Rep., Edmonton.

Poston, B. 1991. An overview of federal (Environment Canada) involvement in programmes to alleviate waterfowl damage to agricultural crops on the Canadian prairies in the 1980s (with emphasis on 1982 to 1987). Can. Wildl. Serv. Rep., Edmonton.

SAS Instit. 1990. SAS/STAT user's guide: Vol. 1 and 2. SAS Instit. Inc., Cary, N.C.

Sugden, L.G. 1976. Waterfowl damage to Canadian grain: current problem and research needs. *Can. Wildl. Serv. Occas. Paper 24.* Ottawa.

Sugden, L.G., Clark, R.G. Woodsworth, E.J. & Greenwood, H. 1988. Use of cereal fields by foraging sandhill cranes in Saskatchewan. *J. Appl. Ecol.* 25:111-124.

Thomas, G.J. 1981. Field feeding by dabbling ducks around the Ouse Washes, England. *Wildfowl* 32:69-78.

Weller, M.W. 1969. Comments on waterfowl habitat and management problems in Argentina. *Wildfowl* 20:126-130.

Zar, J.H. 1984. *Biostatistical analysis.* Prentice-Hall Inc., Englewood Cliffs, N.J.

Robert G. Clark, Canadian Wildlife Service, Prairie and Northern Wildlife Research Centre, Saskatoon, Sask., Canada S7N 0X4.
Hugh Boyd, Canadian Wildlife Service, National Wildlife Research Centre, Ottawa, Ont., Canada K1A 0E7.
Bert Poston, Canadian Wildlife Service, Edmonton, Alta., Canada T6B 2X3 (Retired).