AN APPROPRIATE WELFARE MEASURE OF WILDLIFE DAMAGE

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Abstract

This paper derives the welfare loss to landowners from wildlife damage, which is not the same as the value of yield loss. The paper then estimates the welfare loss to Ontario landowners using willingness to tolerate losses as an indication of on-farm wildlife benefits. Results for Ontario fieldcrop producers in 1998 suggest that the welfare loss is 50% of the value of the yield loss. Willingness to tolerate losses varies by several variables including wildlife species and crop type.

I. Introduction

Various policies, including compensation, insurance, abatement cost sharing programs, and contracting for control services, have been implemented in response to wildlife damage on private lands (Yoder 2000; Van Tassell, Phillips and Yang 1999; Wagner, Schmidt and Conover 1997; Gray and Sulewski 1997; Rollins and Briggs 1996; Gray and Rollins 1995). The economic literature has addressed implications of policy instruments, property rights arrangements, market mechanisms, moral hazard, abatement incentives and other theoretical issues related to the economic problems posed by these policies and problem of wildlife damage in general. A number of empirical studies have estimated the dollar value of wildlife damages to agricultural commodities on private lands (Yoder 1999; McNew and Curtis 1997; Conover 1994; Wywialowski 1994; Conover and Decker 1991; Vecellio et al. 1989; Decker and Brown 1982; Brown et al. 1978; Connelly 1987).

The existing studies appear to presume that the appropriate measure of damage is the market value of yield losses to farmers. This paper suggests that for most wildlife damage policies, the appropriate damage measure is the welfare loss to landowners, which is not necessarily the same as the market value of the loss in yields. Because landowners may receive benefits from wildlife, a damage estimate should attempt to net these benefits from the value of yield losses[1]. The paper derives a welfare measure for losses net of wildlife benefits, and then develops and applies an econometric model to estimate the welfare loss from wildlife damage during the 1998 growing season to Ontario field crop producers.

A number of wildlife management studies focus on the fact that agricultural producers indicate they will tolerate some level of wildlife damage because they enjoy the presence of wildlife on their land for recreation and aesthetic reasons (Pomerantz et al., 1986; Siemer and Decker, 1991; Craven et. al. 1992; Brown et al 1978; Decker and Gavin 1985; Enck et al, 1988; Purdy and Decker 1985). Wildlife managers have sought to identify what factors affect producer tolerance levels in order to set wildlife targets and to predict under what circumstances damage may result in undesirable conflicts between farmers and wildlife managers. Results from this literature indicate that producer tolerance levels vary according to personal attitudes, preferences, farm characteristics, type of species causing damage and commodity (Pomerantz et al., 1986; Siemer and Decker, 1991).

In the context of a study of damages caused by while tailed deer in New York, Connelly et al. (1987) suggest that the appropriate measure of wildlife damage should be net of the benefits that people derive from deer. They estimate a 'tolerance threshold,' which they assume represents the amount of damage people are willing to tolerate in return for having deer in their neighborhood. While the concept of tolerance has economic implications, the method that Connelly et al use to estimate tolerance is not consistent with economic theory. We are unaware of any published economic study that explicitly defines wildlife damage as net of benefits

This study incorporates tolerance as a measure of the farmer's willingness to absorb losses from wildlife damage, and defines a welfare measure for wildlife damage net of benefits. We hypothesize that landowners have an endowment of willingness to absorb losses. Willingness to absorb damage indicates that for some level of damage the farmer is indifferent between no damage and damage, leaving utility constant. The acceptable range of damage should be subtracted from the physical damages since utility remains unchanged.

II. The Model

We assume that a farmer's utility depends on the on-farm wildlife population, W, and a vector of all other goods, X. The on-farm wildlife population affects utility in two ways. Wildlife benefits increase utility, while lost income from damaged crops decreases utility. This is illustrated using the farmer's indirect utility function, which can be written:

$$V = V(P, B(\cdot), I - D(\cdot)), \qquad [1]$$

where, P is the vector of prices corresponding to the vector of all other goods, X, and I is farm income. It is assumed that P is constant and is henceforth suppressed. D(·) is the monetary value of wildlife damage to crops and B(·) represents utility from wildlife. Both are functions of other variables:

$$D(\cdot) = D(S, W, C, L, A, G) \qquad [2]$$

$$B(\cdot) = B(S, W, C, L, T, H, E) \qquad [3]$$

where S is wildlife species, W is the size of the on-farm wildlife population, C is crop type, L is farm location relative to nearby protected areas, A is on-farm damage abatement effort, G is crop acreage, T describes individual farmers' attitudes toward wildlife, H describes individual farmers' attitudes toward hunting and E represents dependence on farm income.

The model distinguishes between two forms of benefits that a farmer may derive from providing wildlife habitat. The first is the direct use benefit from activities such as hunting and from aesthetic enjoyment. The second is utility received from exercising a stewardship role, and fulfilling an expectation that agricultural productivity includes responsibility for a minimal level of wildlife habitat provision. Thus, a landowner who does not directly derive benefits from blackbirds or raccoons consuming crops may receive utility from having fulfilled a part of their stewardship responsibility. This latter category accounts for tolerance of damage from wildlife considered to be nuisance species.

Widlife Use Benefits

Use benefits are measured in units of wildlife population. It is assumed that use benefits exhibit typical characteristics of a normal good, and utility is increasing at a decreasing rate over the wildlife population. The relationship between utility and wildlife use benefits is:

$$\frac{\partial \mathrm{V}}{\partial B} \cdot \frac{\partial B}{\partial W} > 0 , \qquad \frac{\partial^2 \mathrm{V}}{\partial \mathrm{B}^2} \cdot \frac{\partial^2 B}{\partial W^2} < 0 \qquad [4]$$

We assume that utility is increasing at a decreasing rate as income increases:

$$\frac{\partial \mathrm{V}}{\partial \mathrm{I}} > 0, \qquad \frac{\partial^2 \mathrm{V}}{\partial \mathrm{I}^2} < 0 \qquad [5]$$

Further, we assume that for a given on-farm wildlife population, W^o, if $I^o > I^1$, then:

$$V^o(W^o; I^o, P) > V^1(W^o; I^1, P) \qquad [6]$$

Maximum potential farm income, I^{max}, is the level of income achievable when the on-farm wildlife population is zero. Thus, as the wildlife population in Figure 1 increases from 0 to W^1, crop damage increases from 0 to D^1 and net income decreases from I^{max} to I^1 ($I^1 = I^{max} – D^1(W^1)$). The decrease in income from wildlife damage reduces utility from V^0 to V^1.

We assume that any on-farm wildlife results in some damage, so that $\partial D / \partial W \geq 0$. It follows from equations [1] through [5] that the net effect of a marginal change in the on-farm wildlife population on utility, $\partial V / \partial W$, is represented by:

$$\frac{\partial V}{\partial W} = \frac{\partial V}{\partial B}\frac{\partial B}{\partial W} + \frac{\partial V}{\partial D}\frac{\partial D}{\partial W} \quad [7]$$

The first term on the right-hand side, marginal utility of wildlife benefits, is positive, while the second term, marginal utility of income loss, is negative. Therefore, the sign of the marginal change in indirect utility from a marginal change in *W* depends on the relative magnitudes of each, as illustrated in Figure 2. Thus, as *W* increases, it would generally be the case that over an initial range of *W*, $V_W > 0$; when the marginal utility of wildlife benefits is equal to the marginal utility of income loss, $V_W = 0$; and for greater levels of *W*, $V_W < 0$. Therefore, if a farmer should derive some benefit from on-farm wildlife populations, then utility is maximized at some optimal on-farm wildlife population, $\overline{W}_B$, and optimal damage costs, $\overline{D}(\overline{W_B})$, are non-zero. This threshold, $\overline{W}_B$, defines the maximum level of damages from on-farm wildlife populations that would be tolerated by a landowner. Figure 3 illustrates the combined marginal effects on utility from wildlife benefits and income loss on utility. The farmer's threshold for damage, $\overline{W}_B$, is defined as a maximum level of 'willingness to tolerate' (WTT) wildlife damage.

Wildlife Stewardship Benefits

It is assumed that the farmer has an endowment of utility that can be derived from having fulfilled a passive stewardship role. This endowment does not add to utility in the absence of wildlife damage, but as damage occurs, the endowment compensates for losses up to a point. The endowment absorbs the disutility caused by damages, but does not result in a net gain in utility. At levels below the threshold, damages are merely absorbed and stewardship benefits do not result in a net gain in utility. When the endowment is exhausted, any increases in damage cause a loss in utility. Some nuisance species, such as raccoons, or blackbirds may not provide use benefits to landowners, but the landowner with an endowment of passive stewardship utility may nevertheless be willing to absorb some damage from these species. An individual farmer's endowment of compensating passive stewardship utility implies a second element in a threshold for maximum willingness to absorb wildlife damage, denoted as $\bar{S}(\overline{W}_S)$.

We assume that utility from stewardship is increasing over wildlife population at a rate that asymptotically approaches a constant. As the level of stewardship provision approaches the limit $\bar{S}$, the marginal change in utility from stewardship provision approaches zero. The net marginal impact of on-farm wildlife on utility through stewardship provision depends on the magnitudes of the individual effects of stewardship benefits and income loss, similarly with wildlife use benefits. It follows that there is a range of damages where marginal utility from stewardship exactly offsets the marginal disutility from lost income. This range is illustrated in Figure 4 as the portion of the marginal utility from on-farm wildlife, to the left of $\bar{S}(\overline{W}_S)$. Over the bracketed range between I_{max} and $\bar{S}$ the marginal change in utility as a result of damage is essentially zero. Beyond $\bar{S}$, the loss in utility from damage outweighs the utility from stewardship provision, and utility decreases.

The net effect on utility is illustrated in Figure 5. To the left of $\bar{S}(\overline{W}_S)$, utility is constant since the loss in utility is exactly offset by the increase from stewardship provision. Where utility is unchanged, the farmer is indifferent to no damage and damage. Beyond $\bar{S}(\overline{W}_S)$, utility begins to decrease at an increasing rate. An endowment of stewardship benefits would absorb the loss of utility for damages to the left of $\bar{S}(\overline{W}_S)$. A farmer would be willing to tolerate damages up to $\bar{S}(\overline{W}_S)$, since net utility is unchanged. Finally, it is possible that some farmers may derive zero utility from wildlife, therefore any level of damage causes a decrease in utility since there are no benefits to offset the decrease in income caused by damages. These farmers would therefore have a zero tolerance for damage.

An individual landowner's maximum willingness to tolerate damages, $\bar{T}(\overline{W}_B, \overline{W}_S)$, is a function of the stewardship endowment and wildlife use benefits. The following representation of the model does not explicitly distinguish between the two types of benefits, and refers to the combined threshold. The empirical model, however, provides a means to test for potential differences in the level of the threshold by wildlife species, with the implicit assumption that a positive threshold for nuisance species (such as raccoons or blackbirds) indicates some utility from stewardship benefits. It would not be expected that the presence of nuisance species would increase utility, but the stewardship benefits would explain a willingness to tolerate some damage by these species.

With either type of wildlife benefit, the threshold level of damage, $\overline{T}$, is defined as the maximum willingness-to-tolerate wildlife damage. Any damage beyond $\overline{T}$ represents a welfare loss, such as illustrated in Figure 6. In this context, V^o is utility associated with $\overline{T}$, and V^1 is utility associated with damage level $D_1(W_1)$, where income is $I^{max} - D_1(W_1)$. The quantity M is the difference between $I^{max} - D_1(W_1)$ and the maximum willingness to tolerate damages. That is, M is defined as:

$$M = D_1(W_1) - \overline{T} \qquad [8]$$

Thus, the appropriate economic welfare measure of damage is defined as the amount of money required to keep the farmer at the maximum utility. The change in welfare is expressed as:

$$V^0(I) = V^1[I - D(\cdot), B(\cdot)] + M\,, \qquad [9]$$

where M is the level of income that a farmer would need to be compensated to achieve utility level V^0. The welfare measure of damage can therefore be estimated as the value of yield loss net of the maximum amount $\overline{T}$ that farmer is willing to tolerate in damages.

We consider $\overline{T}$ in the context of a random utility model, where $\overline{T}$ is the maximum willingness to absorb losses from wildlife. In this form, the model is suggests an estimable equation for $\overline{T}$. The farmer's indirect utility function can be written as:

$$V = V[I - D(\cdot), B(\cdot)] + \mathbf{e}\,, \qquad [10]$$

where $V(\cdot)$ is the portion of utility that is attributable to observed factors and ε is an error term accounting for the unobservable portion of utility. Over a population of farmers, a farmer would be willing to tolerate a given level of damage if the value of benefits (B) from on-farm wildlife is greater than or equal to the value of damage (D):

$$V_1[I - D(\cdot), B(\cdot)] + \mathbf{e}_1 \geq V_0(I) + \mathbf{e}_0 \qquad [11]$$

where V_0 is indirect utility with zero damage (no wildlife) and V_1 is indirect utility with a given level of wildlife damage (wildlife population is greater than zero). The probability that a farmer would be willing to tolerate a given level of wildlife damage is given by:

$$\Pr(\text{tolerable}) = \Pr[V_1(I - D(\cdot), B(\cdot)) + \mathbf{e}_1 \geq V_0(I) + \mathbf{e}_0] \qquad [12]$$

Rewriting equation 12, we get:

$$\Pr(\text{tolerable}) = \Pr[\mathbf{e}_0 - \mathbf{e}_1 \leq V_0(I) - V_1(I - D(\cdot), B(\cdot))] \qquad [13]$$

Thus, if a sampled population of farmers experiences a range of damages, then the probability that the damage sustained by a given farmer is tolerable can be calculated over the range of damages in the sample.

The Data

The data was obtained from a survey of Ontario field crop producers conducted in spring of 1999, which determined wildlife damages for the 1998 growing season. No one in the sample received any type of damage compensation, insurance or cost recovery for abatement effort, since these options where unavailable. Survey questions were designed to collect information regarding wildlife damage in Ontario. Questions pertained to the things that affect farmers' attitudes, decisions or behavior toward wildlife and wildlife damage, such as abatement practices, individual tolerance toward wildlife and wildlife support activities. Survey questions were grouped into 5 main categories: 1) farm characteristics, 2) landowner actions, activities and attitudes toward wildlife, 3) on-farm wildlife population levels, 3) yield losses due to damage and 4) abatement activities. Respondents who reported damage were asked whether the levels of damage that they sustained were tolerable.

A random sample of participants was obtained by random digit dialing from a list of Ontario farmers. The farm list is continually updated and information is frequently compared to census figures to ensure data is representative of the Ontario farm population.[2] In early May 1999, 1043 surveys were distributed by mail to survey participants. Of the 1043 surveys sent, 649 were completed, resulting in a 62% response rate. Recruitment was done over five commodity groups - field crops, fruit, vegetables, beef and sheep. The data used for this paper is limited to the sample of field crop producers.

The distribution of losses is highly skewed indicating damages do not occur evenly across farms, as illustrated in Figure 8. The data indicate that some farmers incur a significant amount of loss while the majority has very little. These results are consistent with other wildlife damage studies (Wywialowski, 1994). For farms with wildlife damage, the mean value of loss by crop type ranges from $221.25 for wheat to $1,385.48 for corn.

Respondents were queried about crop yields, damages, abatement practices, perceptions of on-farm wildlife population increases, activities done expressly to create or maintain wildlife habitat on the farm, and about farm characteristics. In the context of reporting damages by crop and wildlife species and abatement practices, respondents were asked to respond either "yes" or "no" to a question that asks whether the damage they experienced during the 1998 growing season by each crop type and wildlife species was tolerable.

Producers were asked to indicate whether they took preventative actions in the last five years. Table 1 shows the percentage of producers taking preventative action in the past 5 years, and average dollars spent and average number of hours invested in 1998. Table 2 reports the number of producers that took preventative action and received damage. These results reveal that the majority of producers that abated reported damage. Likewise, the majority of farmers that did not abate did not receive damage. This suggests that those who have experienced damage in the past are likely to experience damage in the future.

The data are arranged as an unbalanced panel in which each combination of yield loss by crop and wildlife species is expressed by farm. The number of observations for each farmer depend on the number of crops grown that suffered damage, and number of species causing damage. An example of the data structure is given in Table 3.

The number of observations in the panel for field crops is 1206 observations, over 241 different farms. The number of observations without damage is 906 and the number with damage is 300.

The Tolerance Empirical Model

A random effects probit model is used to test for systematic variation across farmers. The data structured the data as a panel where each observation is species and crop specific; therefore, estimates of willingness to absorb losses were obtained for each wildlife species by crop type. We compare the estimated welfare loss to producers with the estimated value of the loss in yields from the same data, showing that the welfare loss is less than yield losses would indicate.

The dependent variable, tolerance, is a binary variable, indicating whether the individual farmer reported that sustained losses where tolerable or not tolerable. The probit model assumes errors are distributed jointly normal with zero mean (Train, 1986). The model is expressed as follows:

$$Y_{ica}^* = \alpha + X_{ica}\beta + \mu_i + \varepsilon_{ica}, \qquad [14]$$

where Y_{ica}^* is the unobserved hidden variable specific to individual *i* and damage from crop *c* (*c* = 1,2,3,4) and species *a* (*a* = 1,2,3,4). X_{ica} is a K x 1 vector of exogenous variables and γ and β are 1 x K vectors of variable coefficients. μ_i is the error term that accounts for the variance across individuals. This term is specific for each individual *i* and is constant across the *ca* observations of each individual. ε_{ica} is the error term accounting for the systematic component across species and crop. The error term, ε_{ica}, accounts for systematic variation by crop and wildlife species. While y* is not observable, we can observe the binary variable, y . Both error terms are assumed to be normally distributed with a zero mean and a variance of σ^2_μ and σ^2_ε respectively. Let $\sigma^2 = \sigma^2_\varepsilon + \sigma^2_\mu$, $\rho = \sigma^2_\mu/\sigma^2$ and impose normalization that $\sigma^2 = 1$. Following Guilkey and Murphy (1993), the probability that $y_i = 1$ is therefore defined as

$$P(y_i) = \int_{-\infty}^{\infty} \Phi\left(\left[\left(\frac{X_{ica}\beta}{\sigma_e}\right) + \mu_i\left(\frac{\rho}{1-\rho}\right)^{1/2}\right][2y_{ica} - 1]\right) * \phi(\nu_i)\,d\nu_i \qquad [15]$$

where $\Phi(\cdot)$ is the normal cumulative distribution function, $\nu_i = \mu_i/\sigma_{i.}$,and ρ is the coefficient representing the level of correlation between the *ca* responses of a given individual. If ρ=0, then correlation does not exist and a simple pooled probit model can be used for estimation. If $\rho \neq 0$, there are systematic components of error that occur within groups. Failure to account for these errors results in biased standard errors of the coefficients. The test statistic for ρ is distributed chi^2 with 1 degree of freedom. Therefore, the model is estimated as:

$$Pr (y = 1) = \Phi (\beta_0 + \beta_1 \$Damage + \beta_3 rev\_crop + \beta_3 public + \beta_4 private + \beta_5 rev\_farm + \beta_6 recr + \beta_7 pop + \beta_8 dcrop1 + \beta_9 dcrop2 + \beta_{10} dcrop3 + \beta_{11} dspecie1 + \beta_{12} dspecie2 + \beta_{13} dspecie3 + \beta_{14} nonuse + \beta_{15} Abate + \beta_{16} Acres)$$

Results from Tolerance Estimation

The results of the random effects probit, summarized in Table 5, indicate that the tolerance function is a significant predictor of the probability that a farmer would be willing to tolerate a given level of wildlife damage. The log likelihood is -177.7907, is significant at 1%. The chi-square test statistic for the rho coefficient is 31.17 and is significant at 1%, indicating that the random effects probit model is preferred over the standard probit.

The results suggest that the tolerance threshold for damage to corn is significantly different from that of the thresholds for wheat, soybeans, and forages and silage, while the probabilities that losses to wheat, soybean, and forages and silage are tolerable are statistically not distinguishable. The parameter estimates for wheat, soybean and forages and silage are positive and significant, indicating the probability of tolerance toward wildlife damage is higher for these crops relative to corn. The probability of tolerance decreases by approximately 8% for corn. Corn may be different from the other crops because of the time of year in which wildlife damage occurs. For example, corn is more likely to be damaged in the fall when the crop is ready for harvest after a farmer has invested and anticipated an expected yield. Whereas, wheat, soybean and forages and grain silage are more likely to be damaged in the spring when less time has been invested in the crop, and farmers have the option of replanting.

The parameter estimates for blackbirds, deer and geese are positive and significant, indicating a lower tolerance toward damage by raccoons than other species. The parameter estimates for blackbirds and deer are similar, 0.5440 and 0.6614 respectively. The similar estimates reveal that farmers' tolerance does not vary significantly by blackbirds or deer. The parameter estimate for geese, 1.3579, is significantly larger than the estimate for blackbirds and deer. The probability of tolerance toward damage caused by geese is 11% higher than for raccoons. These results suggest that farmers' tolerance thresholds are highest for damage by geese.

As was expected, farmers are less tolerant of damage by the traditional nuisance species which provide for little in the way of wildlife use benefits than those species which would be expected to provide direct use benefits. The tolerance thresholds are lower for raccoons and blackbirds than for deer and geese. Damage from raccoons is least tolerated followed by blackbirds, deer and geese. While landowners don't encourage blackbird or raccoon on-farm populations nor receive any added utility from the on-farm populations of these and other nuisance species, the willingness to tolerate some damage from these species is consistent with the notion that the tolerance threshold may include an endowment of good will, or stewardship benefits.

Farmers who do not perceive an increase in their on-farm wildlife populations have an 8% increase in the probability that they would be tolerant of a given level of damage. Those farmers who perceive an increase in wildlife populations on their farms are more likely to have experienced damages in the past, and anticipate a cumulative impact.

The percentage of household income from farming, Rev_farm, and the percentage of farm income from field crops, Rev_crop, were both included in the tolerance model. Rev_crop is significant at 10% while Rev_farm is not. The sign on parameter estimate for "Rev_crop" is negative, suggesting that the probability of a tolerable response decreases as the percent of farm revenue from field crops increases. This is similar to findings in previous studies (Siemer and Decker, 1991).

The positive "nonuse" parameter estimate reveals that farmers who value wildlife for nonuse purposes have a higher tolerance level than those that do not hold these values. The probability of tolerance for damage increases by 10% when farmers value wildlife for nonuse purposes. This result is expected because farmers with nonuse values derive benefits from wildlife on their farm, which increases their tolerance threshold.

The sign on the parameter estimate "recreation" is negative, which is opposite of what was expected. The parameter is significant at the 5% level. The probability of willingness to tolerate a given level of damage is 8% less for farmers who do not value wildlife for recreation. The negative sign suggests that farmers who do not value wildlife for hunting or trapping may view these activities as cruel or wrong. It is possible that farmers who do not hold these values derive higher benefits from wildlife for nonuse purposes than the benefits derived by farmers with recreational values.

The parameter estimates for the variables “public” and “private” suggest that the probability that a farmer would be willing to tolerate a given level of damge is not significantly affected by the proximity to a protected wildlife area.

The results on the variable acreage indicate support for the edge effect, which is related to wildlife foraging patterns. Wildlife is more likely to graze along the perimeter of crops and along ditches. Therefore, as the acreage increases the proportion of damage decreases. A 10% increase in acreage results in a 0.5% increase in the probability of a tolerable response. This suggests that tolerance is not very sensitive to acreage.

The null hypothesis that tolerance does not decrease as wildlife damage increases is rejected at 1% significance level. However, the damage elasticity is 0.03, which indicates that tolerance is not highly sensitive to this variable. The negative relationship indicates that the probability of tolerance decreases as the dollar value of damage increases. This result is expected since higher dollar values of damage reduce the net income from farming. The higher the dollar value of damage, the more likely the disutility from damage will exceed the utility from benefits.

The results indicate that farmers who abate have a lower tolerance threshold for wildlife damage. This is expected since money and time has been expended to prevent wildlife damage. In other words, some of the tolerance toward wildlife has been used up on the expense and time of abating. This results in a lower tolerance toward damage. A change from 0 (base case - no abatement) to 1 (abatement) results in a 20% increase in the probability of a tolerable response. Past abatement effort is the most sensitive factor affecting the probability that a given level of damage is tolerable.

The results reveal that the following variables are significant predictors of tolerance: level of damage, species, crop, perceived wildlife population, abatement, nonuse values and recreation values. Whether a farmer abated or did not abate appears to be driving the probability that a given level of damage is tolerable. The type of wildlife species causing damage also has a large impact on whether a farmer is likely to tolerate wildlife damage. This result suggests that farmers derive fewer benefits from species that are typically considered as pests.

Calculation of the Maximum Level of Damage that farmers are Willing-to-Tolerate

The probability of the level of willingness-to-tolerate is estimated over the range of damages in the sample. The following equation was used to derive the probability curves in Figure 8.[3]

$$\frac{1}{1 + EXP^{(-(b0 + b1*Avg + ...))}} \quad [16]$$

Each parameter estimate from the tolerance function is multiplied by the corresponding average value for continuous variables, and 0 or 1 for dummy variables. Median values of willingness-to-tolerate are the dollar values of damage taken where the probability of a "yes" is equal to 50%.

Figure 8 shows the probability of tolerance by crop type for a given level of damage. The probability of tolerance is high at lower levels of damage and low at higher levels of damage.   Table 6 reports the median values of willingness-to-tolerate by each crop type and average across species. The average values of willingness-to-tolerate can be interpreted as the level of benefits received by an average farmer. These values reveal that farmers are more willing to tolerate damage by wildlife for forages and silage crops, as illustrated in Figure 8. For corn, the dollar value of damage farmers are willing to tolerate is much lower, indicating that the wildlife benefits are lower. As mentioned earlier, this may be due to the time of the season in which wildlife damage occurs.   Another potential reason may be that corn is the primary crop grown in a rotation.   Therefore, damage to corn would have a greater impact than damage to a less important crop included in the rotation.

Average willingness-to-tolerate is calculated for crop type and wildlife species.   These values are approximately $1,750 for corn, $2,300 for forage/silage, $2,500 for soy and $2,400 for wheat. Table 6 shows the median values by crop and species. These values suggest that the average farmer is willing to tolerate higher losses due to geese damage than damage that is caused by blackbirds, deer or raccoons. Farmers have the lowest value of willingness-to-tolerate when raccoons cause damage.

Welfare Loss Estimates

The welfare loss estimates were obtained by identifying the observations with actual damage levels greater than the estimated median level of willingness-to-tolerate. The median willingness-to-tolerate was subtracted from each of these observations and summed to give the total welfare measure of damage. Average values of tolerance were increased and decreased by 20% to determine the magnitude of change in the welfare measure of damage. Welfare estimates of loss are compared with the yield loss to show the difference in the damage measures. These results are given in Table 7. Welfare losses are highest for corn and are zero for wheat. Varying tolerance values by 20% does not significantly affect the value of the welfare loss. The magnitude of difference between the value of the yield loss and the value of welfare loss is greatest for wheat, and soybean. The welfare loss for corn is approximately 50% less than the value of yield loss and forages and silage is 40% less. These results indicate a significant difference in a welfare measure of damage and a yield loss measure of damage.

An estimate of the aggregate welfare measure of damage is obtained by calculating the probability of welfare loss multiplied by the number of Ontario producers and the value of the average welfare loss. Aggregate estimates of welfare loss are given for corn and soybean in Table 8. Aggregate damage estimates for wheat are not given because of the small number of observations with yield loss included in the panel.

Empirical Model of a Damage Function

A damage function was estimated to provide more information on the variables that affect the level of damage as well as the magnitude of these affects. The distribution of damages in the sample are highly skewed, as illustrated in Figure 7. The skewed distribution is normalized by taking the natural log of the dollar value of damage. A tobit model is used to explain variation in damage level. The tobit specification is:

$$\begin{aligned} y_i &= \mathbf{b}' x_i + u_i \quad \text{if } \mathbf{b}' x_i + u_i > 0 \\ y_i &= 0 \quad \text{otherwise} \end{aligned} \qquad [17]$$

where β is a vector of unknown parameters, x_i is a vector of explanatory variables and u_i are residuals that are independently and normally distributed with mean of 0 and a common variance of σ^2.[4]

Damage Function Results

The damage function provides some insight on the probability of damage depending on the crop and wildlife species. The results, summarized in Table 9, reveal that the model is highly significant in predicting the probability of damage. The rho coefficient indicates that the random effects model is a better fit than the standard tobit.

Relative to raccoons, the base case, the probability of damage increases by 15% when damage is caused by deer and decreases by 18% and 20% when damage is caused by blackbirds or geese. The probability of damage is the lowest when species is geese, followed by blackbirds, raccoons and deer. These results suggest that crop damage is more likely to occur from deer and raccoons than blackbirds or geese.

The null hypothesis that damage varies by crop type can be rejected for corn but not for soybean, wheat, or forages and silage. The probability of wildlife damage is highest for corn, about 18% higher than for other crops. The results indicate that the probability of damage does not vary significantly between soybean, wheat or forages and silage. The null hypothesis that damage is not higher for land located near public or private protected areas cannot be rejected.

The null hypothesis that damage is not lower for farmers that abate cannot be rejected. The sign on the parameter coefficient is opposite of what was expected. The coefficient is positive and is significant at the 1% level. The size of the coefficient, 5.1141, indicates that “Abate” is driving the damage function. For those who do not abate, the probability of damage is approximately 20%. For those who abate, the probability of damage increases to 98%. The descriptive statistics suggest that “Abate” is a proxy for past experience. Those who expect damage take preventative action and those who do not expect damage do not take preventative action.

Implications

The use of agricultural lands by wildlife for habitat and food often results in yield loss to farmers. In many cases these losses are insignificant and farmers indicate that they are willing to tolerate the damage they experience. The level of tolerance toward wildlife damage can be interpreted as indicative of benefits farmers receive from on-farm wildlife. These results suggest that the appropriate welfare measure to use when referring to crop damages in the context of wildlife damage policy should be net of benefits from wildlife. These benefits can be estimated as a maximum willingness to tolerate losses. While tolerance thresholds have been widely documented in the wildlife management literature, we are unaware of other applied economic models of wildlife damage that recognize the implications of wildlife damage tolerance by agricultural producers.

Several implications for policy can be drawn from the results of this study. First, this research demonstrates that not all crop yield loss resulting from wildlife activity should be defined as an economic loss to farmers. The results from this study indicate that the welfare measure of damage to field crops in Ontario for 1998 is less than half of the value of yield loss from wildlife damage. Given these results, it is safe to conclude that wildlife damage policies in general that are based on the value of yield loss are likely to overstate economic damage. Overstated damage could result in non-optimal levels of wildlife, abatement and agricultural commodities.

The results of this application indicate that damage was not a significant problem for most field crop farmers in Ontario for 1998. However, for those that did experience significant losses, an appropriate policy may involve focusing on damage abatement rather than compensation.

In the past, wildlife managers have attempted to determine the factors affecting landowner tolerance in order to predict when and where potential conflicts may arise. The tolerance function developed in this study can be used to determine the marginal impact of each factor on landowner tolerance. This will allow wildlife managers to predict more accurately when and where problems may arise and the impact of specific variables on the level of tolerance.

It should be noted that the data used in this study do not appear to suffer from moral hazard. Several reasons can be suggested to support this conclusion. First, compensation is not available for field crop producers included in the data sample. Second, the survey questions were worded in such a way that the tolerance portion of the survey did not have a direct link to future policy options to deal with Ontario wildlife damage problems. Third, farmers in attendance at focus groups and workshops indicated that abatement assistance is preferable to compensation programs. The province does not currently have a wildlife damage policy.

The main contribution of this study is the theoretical model of a welfare measure of wildlife damage. This contribution is significant because it provides a more accurate picture of the losses from wildlife damage to agriculture. Other damage estimates based on yield loss overstate damage since benefits from wildlife are not netted out. The magnitude of the difference between the value of yield loss and the welfare measure of damage is approximately 50%. The difference between the value of yield loss and the welfare measure of damage indicates that for this study most farmers were willing to tolerate the wildlife damage they experienced.

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Figure 1 Relationship Between Indirect Utility and Income

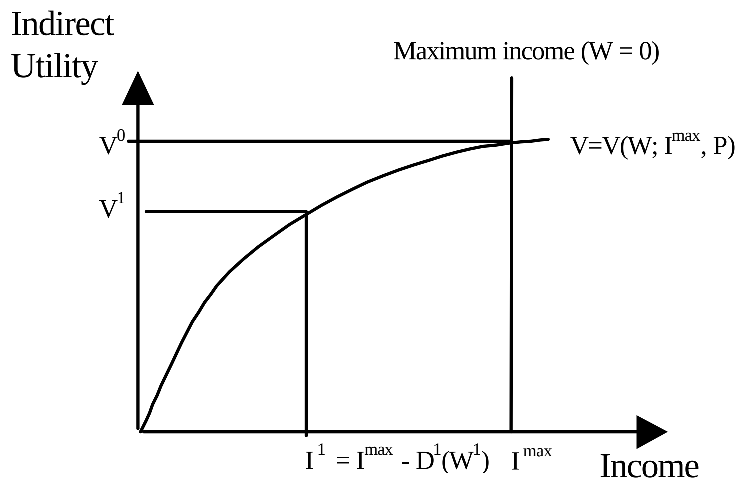


Figure 2. Marginal Utility of Income and Marginal Utility of Wildlife Use Benefits

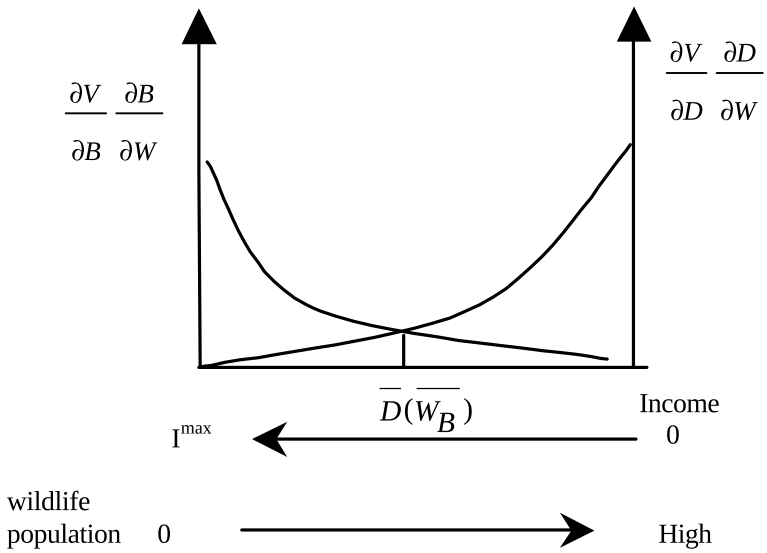


Figure 3   Maximum Willingness to Tolerate Damage for Wildlife Use Benefits

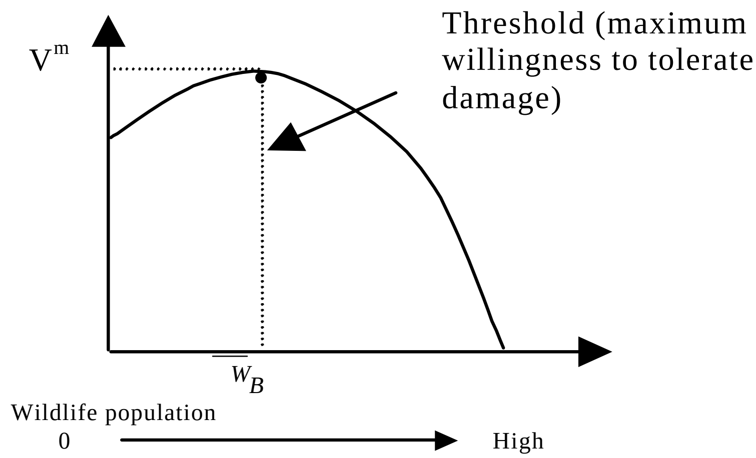


Figure 4 Marginal Utilities of Income and Wildlife Stewardship Provision

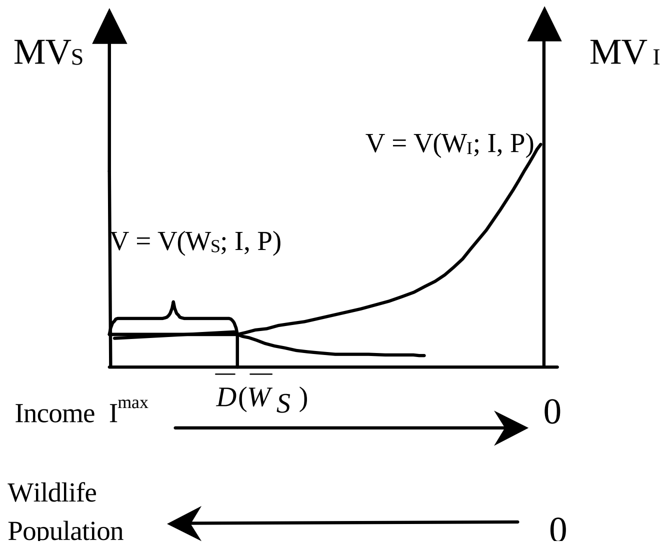
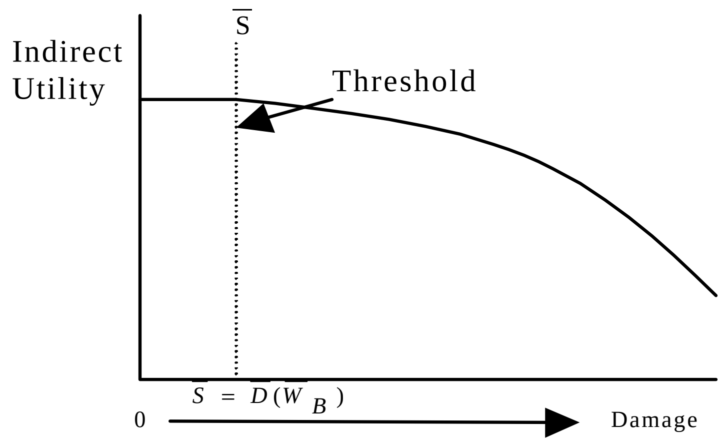


Figure 5   Maximum Willingness to Tolerate Damage for Stewardship Benefits



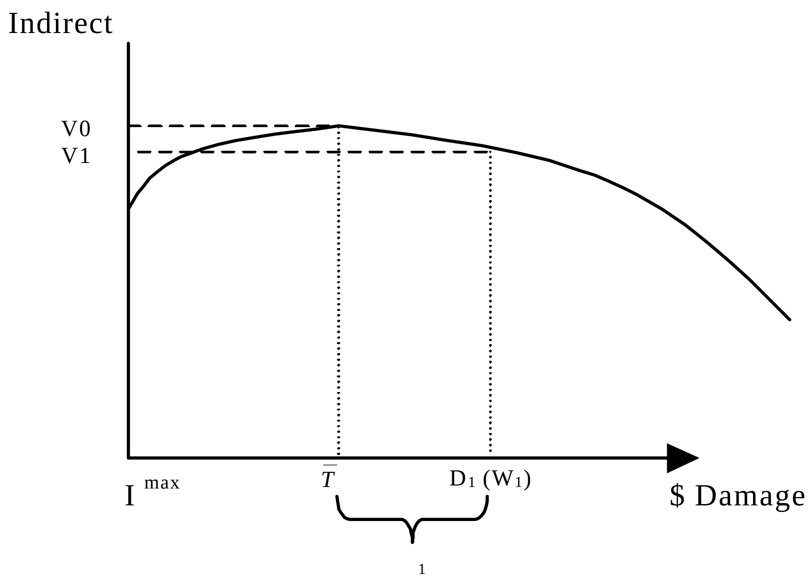


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Figure 7 Ordered distribution of Yield Losses for Ontario Field Crop Producers

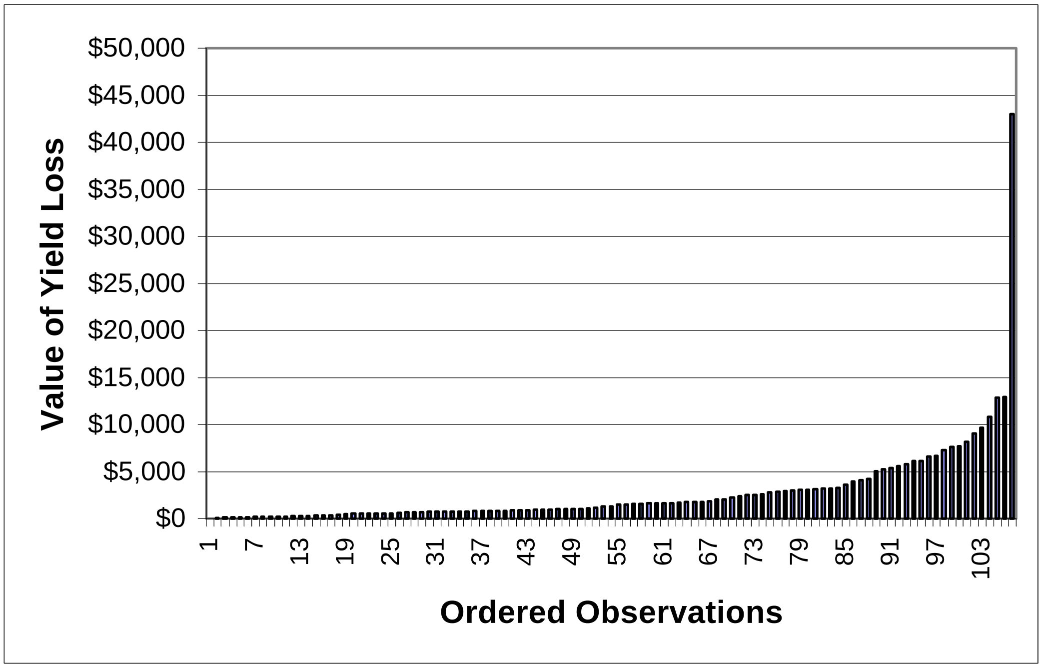


Table 1 Proportion of Producers Taking Preventative Action and Average Abatement Investment

Proportion of Producers Taking Preventative Actions in Last Five Years		**Average Annual Investment in Prevention Activities Per Farm (1998-1999)**	
	Percent of Total Producers	Material Investment	Hours
Geese	16%	$115	20
Blackbirds	11%	$142	12
Deer	12%	$175	24
Raccoons	40%	$167	25

Table 2 Number of Producers That Took Preventative Action in the Last 5 Years and Received Damage in 1998

	Geese		**Deer**		**Raccoons**		**Blackbirds**	
	Damage	No Damage	Damage	No Damage	Damage	No Damage	Damage	No Damage
Abatement	16	15	37	3	66	7	8	4
No Abatement	30	327	73	176	36	123	26	248

Table 3 Example of the Panel Structure

Farm I.D. #	**Species**	**Crop**	**Damage**	**Damages were tolerable**
1	Deer	Grain	$124.50	Yes
1	Raccoon	Corn	$1,023.56	No
2	Deer	Soybean	$859.36	No
2	Geese	Corn	$22.77	No
3	Blackbird	Soybean	$23.86	Yes
3	Raccoon	Soybean	$950.00	Yes
3	Raccoon	Corn	$2,570.84	Yes

Table 4 Summary of Variables

Abbreviation	Variable	Definition	Variable Type
dcrop	Crop dummy	Dummy for crop type	Dummies
dspecies	Species dummy	Dummy for wildlife species	Dummies
population	Perception of wildlife population changes	Respondent's perception of change in wildlife population over past 5 years.	1= Increased 0= not increased
Rev_crop	Revenue from field crops	Percentage of farm income from field crops.	Continuous variable ranging between 1 and 100
Rev_farm	Revenue from farming	Percentage of household income from farming activities.	Continuous variable ranging between 1 and 100
Nonuse	Nonuse values	Respondent rating of the importance of wildlife for education and aesthetics.	1= important 0= not important
control	Control of insects or rodents	Respondent rating of the importance of wildlife for the control of insects or rodents.	1= important 0= not important
recreation	Recreational values	Respondent rating of the importance of wildlife for recreational purposes	1= important 0= not important
Public	Public protected areas	within 2 km proximity to public protected areas such as parks.	1= less than 2 km 0= further than 2 km
Private	Private protected areas	within 2 km proximity to private protected areas.	1= less than 2 km 0= further than 2 km
Acres	Crop acreage	Number of acres specific to each crop type	Continuous variable
Damage	$ Value of yield loss	Value of yield loss by crop type and wildlife species type.	Continuous variable
Abate	Abatement	Preventative action taken to control damage.	1= yes 0= no

Table 5 Results From the Random Effects Probit Model

Variable	Parameter Estimates Model I	Model II	Model III
Forage	**0.4909** **(.3892)**	0.3349 (.3555)	0.79211 (.3055)
Soybean	**0.2211** **(.3546)**	0.3076 (.3600)	0.3136 (.3347)
Wheat	**0.6125** **(.4230)**	0.4695 (.3948)	0.8937 (.3575)
Blackbird	**0.5264** **(.3113)**	0.5492 (.3121)	0.5151 (.3066)
Deer	**0.6318** **(.2793)**	0.6528 (.2813)	0.6286 (.2752)
Geese	**1.0991** **(.3959)**	1.4117 (.3497)	0.9521 (.3623)
A7_pop	**-0.9190** **(.2968)**	-0.8961 (.2948)	-0.9078 (.2926)
Rev_farm	**0.0064** **(.0050)**	.0062 (.0050)	0.0063 (.0050)
Rev_crop	**-0.0081** **(.0050)**	**-0.0081** **(.0050)**	-0.0079 (.0050)
Nonuse	0.6545 (.3388)	0.6504 (.3391)	0.6470 (.3344)
A10_cont	**-0.0854** **(.4132)**	-0.0812 (.4151)	-0.0911 (.4067)
A10_recr	**-0.5666** **(.3106)**	-0.5678 (.3118)	-0.5518 (.3056)
Public	**-0.4263** **(.3626)**	-.4320 (.3625)	-0.4159 (.3571)
Private	**-0.3872** **(.3432)**	-.3817 (.3438)	-0.3935 (.3392)
Acre	0.0040 (.0013)	0.0040 (.0013)	0.0039 (.0013)
Damage	-0.0014 (.0002)	-0.0014 (.0002)	-0.0014 (.0002)
Abate	-1.2816 (.2642)	-1.2775 (.2654)	-1.2772 (.2609)
Corn * Geese	.2035 (.1704)	0.3253 (.1422)	—
Soybean * Geese	-.2683 (.1817)	—	-0.3985 (.1546)
Constant	1.8406 (.7180)	2.1581 (.7067)	2.2560 (.7064)
Log likelihood	-173.75	-174.89	-174.43
Rho	0.5420	0.5473	0.5313

Note: crop base = corn, species base = raccoons
Z-scores in parentheses

Table 6 Median Values of Willingness-To-Tolerate by Crop and Species

	Blackbirds	Deer	Raccoons	Geese
Wheat	$2,228.00	$2,315.00	$1,828.00	$2,827.00
Soybean	$2,086.00	$2,172.00	$1,686.00	$2,684.00
Corn	$1,595.00	$1,681.00	$1,195.00	$2,193.00
Forage/Silage	$2,171.00	$2,258.00	$1,770.00	$2,771.00

Table 7 Total Value of the Sample Yield Loss and the Estimated Sample Welfare Loss

	Yield Loss	Welfare Loss (Base WTT)	Welfare Loss (Base +20%)	Welfare Loss (Base – 20%)
Corn	$145,135.14	$63,718.40	$56,587.32	$72,791.29
Forage/Silage	$60,183.94	$37,052.64	$32,697.84	$38,894.68
Soybean	$28,677.04	$7,108.73	$5,768.93	$8,881.76
Wheat	$4,197.81	$0.00	$0.00	$0.00
Total	**$238,193.94**	**$107,879.77**	**$95,054.09**	**$120,567.73**

Table 8 Estimated Aggregate Welfare Loss to Ontario Corn and Soybean Producers

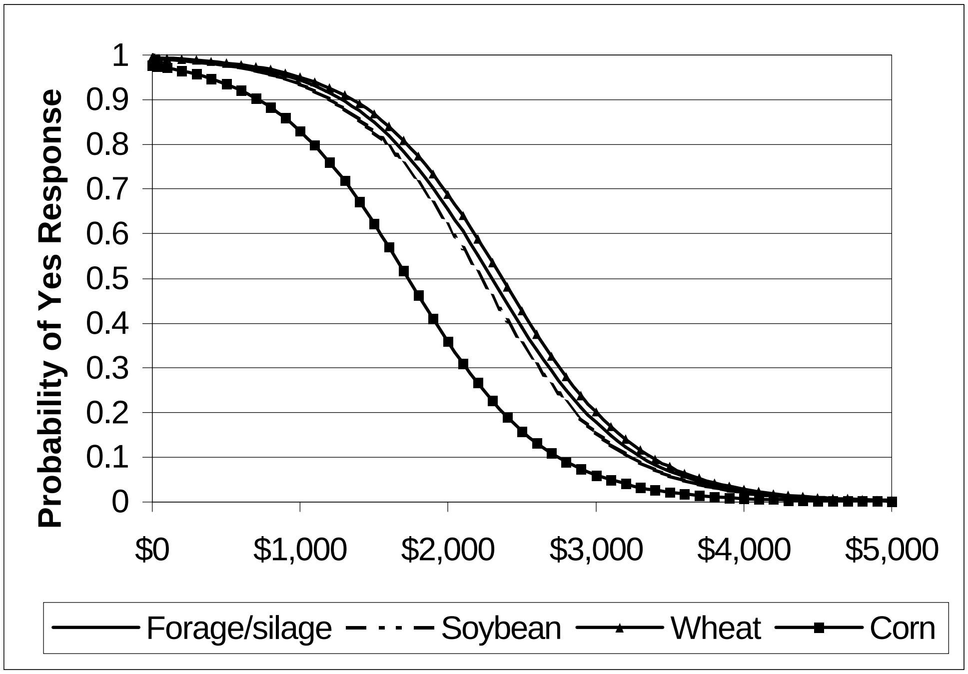
	Yield Loss	Welfare Loss (Base WTT)	Welfare Loss (Base +20%)	Welfare Loss (Base – 20%)
Corn	$17,882,539.15	$7,850,936.88	$6,972,294.46	$8,968,834.51
Soybean	$4,673,859.16	$1,158,599.36	$940,235.26	$1,447,572.06

Table 9 Results From the Random Effects Tobit Model

Variable	Parameter Estimate	Test Statistic
Blackbirds	-2.3169[a]	-4.744
Deer	0.7380[c]	1.806
Geese	-3.2026[a]	-6.918
Forage / silage	-2.5490[a]	-5.399
Soybean	-2.0134[a]	-4.194
Wheat	-2.6761[a]	-4.750
Public	0.8107	0.974
Private	1.0433	1.403
acres	0.0047[a]	4.100
Abate	5.1141[a]	11.015
Constant	-1.7758[a]	-3.159
Log Likelihood = -1067.1101	Number of obs = 1206 Wald chi2 (10) = 313.38 Pro > chi2 = 0.0000	
Rho = 0.6579 Likelihood ratio test of rho=0:	chi2(1) = 123.31 Prob > chi2 = 0.0000	

Note: crop base = corn, species base = raccoons
a - 1% significance level; b - 5% significance level; c - 10% significance level

Figure 8 Probability of Tolerance for Losses by Crop Type



1 Schuhmann and Schwabe (2000) review a number of studies that measure specific wildlife benefits to various user groups.

2 The list of Ontario producers is privately owned by the Angus Reid Group (ARG), which gathers data for research purposes.

3 The logit equation was used to estimate the probability curves because calculations are simpler than the probit. Probit coefficients are divided by 0.625 to make them comparable to the logit model (Maddala, 1983).

4 The likelihood function for the tobit with random effects is: $\Pr(y_i) = \int_{-\infty}^{\infty} \frac{e^{-v_i^2/2\sigma_v^2}}{\sqrt{2\pi}\sigma_v} [p\ F(x_{ica}\beta + v_i)] dv_i$

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