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 approximately half of the value of the yield loss. A number of variables are significant predictors of willingness to tolerate losses, including wildlife species, prevention activity, changes in local wildlife population levels, and landowners perceptions of the recreational and non-use benefits from wildlife.

An Appropriate Welfare Measure of Wildlife Damage

Introduction

A number of studies have estimated the dollar value of wildlife damages to agricultural commodities (Yoder 1999; McNew and Curtis 1997; Conover 1994; Wywialowski 1994; Conover and Decker 1991; Decker and Brown 1982; Brown et al. 1978; Connelly 1987). The existing studies assume that the appropriate measure of damage is the market value of yield losses to farmers. However, in the context of most wildlife damage problems and 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. [1]For landowners who receive benefits from on-farm wildlife populations, the market value of yield losses from wildlife damage would be an upper bound, of an estimate of their welfare loss. This paper derives a welfare measure for wildlife damage that is net of wildlife benefits, and then develops an econometric model to estimate the welfare loss from wildlife damage to Ontario field crop producers during the 1998 growing season.

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 a., 1980; 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 they use to estimate tolerance is not consistent with economic theory. This paper presents an economic model that incorporates tolerance as a measure of the farmer's willingness to tolerate losses from wildlife damage, and defines a welfare measure for wildlife damage net of benefits.

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 and abatement expenditures decreases utility. This is illustrated using the farmer's indirect utility function, which can be written:

$$V = V(P, T(B(W) + S(W)), I - D(W, \cdot)), \quad [1]$$

where *I* is potential farm income, and *D*(·) is income loss from wildlife damage. Potential farm income, I, is the level of income achievable when the on-farm wildlife population is zero. *T*(·) represents the benefit derived from on-farm wildlife populations. *P* is the vector of prices corresponding to *X*. It is assumed that *P* is constant and is henceforth suppressed. Both are functions of other variables:

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

$$B(\cdot) = B(W, J, L, F, H, E) \quad [3]$$

$$S(\cdot) = S(W, J, L, F, H, E) \quad [4]$$

where *J* 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, *F* 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 on-farm wildlife populations. The first are direct use benefits from activities such as hunting and from aesthetic enjoyment, represented by *B*. The second benefit, *S*, is utility received from exercising a stewardship role, and fulfilling an expectation that agricultural productivity includes responsibility for 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.

We assume that on-farm wildlife does not increase farm income, so $\partial D / \partial W \geq 0$. It follows from equations [1] through [4] that the net effect of a marginal change in the on-farm wildlife population on utility, $\partial V / \partial W$, is represented by:

$$\frac{\partial V}{\partial W} = \frac{\partial V}{\partial B}\frac{\partial B}{\partial W} + \frac{\partial V}{\partial S}\frac{\partial S}{\partial W} - \frac{\partial V}{\partial D}\frac{\partial D}{\partial W} \qquad [5]$$

The first two terms on the right-hand side, the marginal utility of wildlife use benefits and the marginal utility of stewardship benefits, are non-negative, while the third term, the marginal utility of income loss is strictly negative. Therefore, the sign on equation [5] depends on the relative magnitudes of marginal wildlife damages and benefits.

Assuming that the first two terms in equation [5] were zero (the farmer receives no benefit from on-farm wildlife), then as the wildlife population in Figure 1 increases from 0 to W^1, crop damage increases from 0 to $D^1(W^1)$ 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. However, if the farmer receives some utility from on-farm wildlife, then either or both of the first two terms may be positive, and the net effect on utility from a change in W depends on the marginal wildlife benefits.

Wildlife Use Benefits, B(W, .)

For simplicity, we can start by assuming that S = 0 and B>0, and normal assumptions regarding the marginal utility of income. Use benefits are assumed to increase at a decreasing rate over the wildlife population. Thus, as Figure 2 illustrates, the net effect is that, $\partial V / \partial W > 0$ over an initial range of *W*; when the marginal utility of wildlife benefits is equal to the marginal utility of damage, $\partial V / \partial W = 0$; and for greater levels of *W*, $\partial V / \partial W < 0$. Therefore, a farmer who derives benefits from on-farm wildlife populations, maximizes utility at some optimal on-farm wildlife population, $\overline{W}_B$, implying that at the optimum damage costs, $\overline{D}(\overline{W_B})$, are non-zero. 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. For the typical ranges of yield losses, the change in marginal utility of income is negligible, so that $\overline{W}_B$ is most strongly influenced by wildlife benefits.

Wildlife Stewardship Benefits, S(W, .)

Now consider the case where B = 0 and S > 0. It is assumed that the farmer derives no use benefits from on-farm wildlife, but does derive utility from fulfilling a passive stewardship role, according to a stewardship endowment. This endowment exactly compensates for losses as they occur, but cannot generate a net gain greater than the maximum utility attainable from farm income alone. Once the endowment is exhausted, increases in damage cause a loss in utility. A landowner with an endowment of passive stewardship utility may thus be willing to tolerate some damage from nuisance species which otherwise provide no use benefits. The contribution of a farmer's endowment of compensating passive stewardship utility to his or her maximum willingness to tolerate wildlife damage threshold is denoted as $\overline{D}(\overline{W}_S)$.

We assume that the benefits from stewardship increase in W to asymptotically approach $\overline{D}(\overline{W}_S)$. As the level of stewardship provision approaches $\overline{D}(\overline{W}_S)$, the marginal utility from stewardship provision approaches zero, while the loss in income is increasing. 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. 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 $\overline{D}(\overline{W}_S)$. Over the bracketed range the marginal change in utility as a result of damage is essentially zero. Beyond $\overline{D}(\overline{W}_S)$ 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 $\overline{S}$, 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 $\overline{S}$, utility decreases at an increasing rate. An endowment of stewardship benefits would absorb some utility loss to the left of $\overline{S}$.

It is also possible that some farmers may derive zero utility from wildlife, so both $B = 0$ and $S = 0$. In this case, 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.

Maximum Willingness to Tolerate Damage

An individual landowner's maximum willingness to tolerate damages, $\overline{T}(\overline{W}_B, \overline{W}_S)$, is a function of the stewardship endowment and wildlife use benefits. The following empirical model does not explicitly distinguish between the two types of benefits, but rather refers to the combined threshold, $\overline{T}$. The model does, however, provide 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 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.

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:

$$M = D_1(W_1) - \overline{T} \qquad [6]$$

Thus, the appropriate economic welfare measure of damage is defined as the amount of money required to keep the farmer at the maximum utility, which is I^{max} - $\overline{T}$. The change in welfare is expressed as:

$$V^0(I) = V^1[I - D(\cdot), T(\cdot)] + M \ , \qquad [7]$$

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 tolerate losses from wildlife. The farmer's indirect utility function can be written as:

$$V = V[I - D(\cdot), T(\cdot)] + \varepsilon \ , \qquad [8]$$

where V(·) is the portion of utility that is attributable to observed factors and ε is an error term accounting for the unobservable portion of utility. A landowner 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):

$$V_1[I - D(\cdot),T(\cdot)] + \varepsilon_1 \geq V_0(I) + \varepsilon_0 \quad [9]$$

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:

$$V_0[I - D(W_T) + T(W_T)] + \varepsilon_0 \geq V_1[I - D(W)] + \varepsilon_1 \quad [10]$$

Rewriting equation [10], we get:

$$\Pr(\text{tolerable}) = \Pr[\ V_0(I - D(W_T) + T) - V_1(I - D(W)) \geq \varepsilon_1 - \varepsilon_0\ ] \quad [11]$$

Thus the probability that the damage sustained by a given farmer is tolerable can be calculated over the range of damages in a sample of farmers that experience a range of damages.

The Data

A 1999 survey of Ontario field crop producers collected information regarding wildlife damage in Ontario 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 were unavailable. Questions pertained to farmers' attitudes, decisions and behavior toward wildlife and wildlife damage. 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) damage prevention activities. Respondents who reported damage were asked whether they were willing to tolerate the levels of damage they sustained that year.[2] An example of the question that was used to elicit the dependent variable is given in appendix A.

A random sample of participants was obtained by random selection from a list of Ontario farmers developed and maintained by Angus Reid, a professional polling and survey research firm in Canada. The farm list is continually updated and information is frequently compared to

Statistics Canada's farm census figures to ensure data is representative of the Ontario farm population.[3] Recruitment was done over five commodity groups - field crops, fruit, vegetables, beef and sheep. In early May 1999, 1,043 surveys were distributed by mail to survey participants. Of these, 649 were completed, resulting in a 62% response rate. The data used for this paper is limited to the subsample of field crop producers.

Figure 8 shows that the distribution of the yield losses is highly skewed, indicating damages do not occur evenly across farms. 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, damage prevention 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 prevention 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.

Table 1 shows the percentage of producers indicating that they undertook preventative actions within the past 5 years, and average dollars spent and average number of hours invested in damage prevention activities during 1998. Table 2 reports the number of producers that took preventative action and received damage. These results reveal that the majority of producers that attempted to prevent damage nevertheless sustained damage. Likewise, the majority of farmers that did not explicitly attempt to prevent damage did not receive damage. This suggests that at least some damage is predictable and that landowners who undertake prevention do so because they have already experienced damage and expect to experience more. Thus, a variable that indicates landowners have practiced preventative actions will be heavily correlated with past damage.

It is hypothesized that a landowner may be more tolerant of damage caused by species of wildlife that provide benefits to the landowner. The data include landowner characteristics that indicate attitudes toward wildlife, and crop losses are broken down by wildlife species. It is also hypothesized that location of land in relation to protected areas may influence a producer's willingness to tolerate damage. That is, a landowner who perceives that a nearby public-owned protected area contributes to crop damage, or reduces the effectiveness of prevention activities, may be less likely to tolerate a given level of damage. The data distinguish between public-owned and private-owned areas that provide habitat in order to control for the notion that landowners may perceive that private owners should have discretion over land use, while public-sector managers should take into account impacts of public land management on nearby private lands.

Table 4 summarizes the variables that are included in the model. The dollar value of damage is estimated as the market value of yield loss due to wildlife damage by crop and wildlife species for each producer. Four crop types (corn, wheat, silage and/or forage, and soybeans) are represented, with four species of wildlife (raccoons, blackbirds, deer and geese). Therefore, a given producer may be included in the dataset as many times as necessary to account for each combination of crop and wildlife species causing damage for that producer.

The percent of household income from farming activities potentially would affect willingness to tolerate a given level of damage. One hypothesis is that households who more heavily rely on farm income are also those for whom farming is a way of life that includes appreciation for the relation between farm activities and stewardship of land resources. However, at lower income levels, landowners who are dependent on farm income may be less tolerant of losses. The percent of total farm income from crop revenue from field crops accounts for the relative importance of field crops in overall farm income. Landowners for whom field crops are a minor source of farm income may be more tolerant of a given level of damage, relative to those for whom field crops are the main source of farm income. The landowner's perception of whether the wildlife population on their land had been increasing over the last five years is included. The notion is that willingness to tolerate a given level of damage may decrease with increases in on-farm wildlife populations.

The Random Effects Model

In order to account for both farm-specific as well as wildlife species-specific effects in estimating willingness to tolerate damages, a random effects probit is used. The dependent variable, tolerance, is a binary variable that indicates whether the individual farmer reported they were willing to tolerate the losses that they sustained. The data are arranged as an unbalanced panel in which each combination of crop type and wildlife species causing damage is expressed by farm. The number of observations for each farmer depends 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 panel for field crops includes 1, 206 observations, representing 241 different farms. The number of observations without damage is 906 and the number with damage is 300. The random effects probit assumes errors are distributed jointly normal with zero mean, and is expressed as follows:

$$Y_{ica}^* = \alpha + X_{ica}\beta + \mu_i + \varepsilon_{ica}, \qquad [12]$$

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) (Greene, 1997). 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 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 the normalization that $\sigma^2 = 1$. Following Guilkey and Murphy (1993), the probability that $y_i = 1$ is therefore defined as

$$P(y_i) = \int_{-\infty}^{\infty} \Phi\left(\left[\left(\frac{X_{ica}b}{\sigma_\varepsilon}\right) + \mu_i\left(\frac{\rho}{1-\rho}\right)^{1/2}\right][2y_{ica} - 1]\right) * f(\nu_i)d\nu_i \qquad [13]$$

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 $\rho=0$, 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.

Results

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 model includes two interaction effects, between corn and geese, and prevention activity and geese. Wildlife species and crop type are dummy variables for which raccoons and corn, respectively, are the bases. The log likelihood is -171.96, and is significant at 1%. The chi-square test statistic for the rho coefficient is 34.38 and is significant at 1%, indicating that the random effects probit model is preferred over the standard probit.

The parameter estimates for blackbirds, deer and geese are positive and significant, indicating a lower tolerance for damage caused by raccoons than for other species. The parameter estimates for blackbirds and deer are similar, 0.6201 and 0.7105 respectively. The similar estimates reveal that farmers' tolerance does not vary significantly by blackbirds or deer. The parameter estimate for geese, 2.123, 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.

Damage from raccoons is least tolerated followed by blackbirds, deer and geese. As was expected, farmers are least tolerant of damage by traditional nuisance species that provide for little in the way of wildlife use benefits. 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.

The perception of on-farm wildlife populations has a significant impact on the willingness to tolerate damage. 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.

Type of crop does in itself not influence willingness to tolerate damage. The exception occurs in the context of the interaction effect between geese and corn. It is not surprising that crop type has no influence, since damage was measured in terms of the market value of the crop, and the damage variable is highly significant. However, anecdotal evidence indicates that geese may pose special problems with corn. Much of these losses occur late in the season when the corn is close to harvest, and probability of losses are in part correlated with weather patterns, how soon the corn can be harvested, and how early the migration starts. Many of the prescribed prevention activities for geese lose their effectiveness after a few weeks. It is reasonable to suggest that increased frustration levels may reduce a landowner's tolerance for crop losses under these circumstances. Thus the interaction effects between geese and corn and geese and prevention actions would be expected to pick up these influences.

The coefficient on the interaction effect of corn and geese together is positive, suggesting that the combination increases the tolerance threshold. However, the interaction effect from prevention and geese is negative and significant, indicating that those landowners who have had past experience with geese damage (and undertook prevention activities during the previous five years) are less tolerant of a given level of damage. The combination of results tells a story that is consistent with the hypotheses.

The positive “Nonuse value” 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 percentages of household income from farming, and the farm income from field crops, were not significant. The parameter estimates for the variable “Public protected area” and “Private protected area” were not significant.

The sign on the parameter estimate “Recreation value” 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. In another part of the survey, farmers were asked to rank the effectiveness of various forms of prevention activities. The majority of landowners ranked hunting as the most effective. However, many noted that there have been barriers to the effective use of hunting pressure, such as no-shooting and/or no-trapping zones near municipal borders, the desirability of allowing unknown people with firearms on their land, and limited availability of permits. It may be that those landowners for whom hunting is an important wildlife benefit are likely to have a lower tolerance threshold, because they consider hunting activity as a remedy for damage. It is also 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 results on the variable for crop 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 dollar value of wildlife damage to crops significantly affects the level of tolerance toward wildlife damage. 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 attempt to prevent damage 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 prevention activities. 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, 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 according to equation [14]:

$$\frac{1}{1+EXP^{(-(\beta 0+\beta 1 * Avg+...))}} \qquad [14]$$

These results were used to derive the probability curves in Figure 8.[4] 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%.

Average willingness-to-tolerate is calculated for crop type and wildlife species. These values are approximately $2,485 for corn, $2,338 for forage/silage, $2,290 for soybean and $2,445 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 presented in Table 7. Welfare losses are highest for corn and are zero for wheat, since the levels of losses are below the tolerance threshold 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.

A comparison between Figures 8 and 9 indicates the effect of abatement on willingness to tolerate damages caused by geese to corn. Figure 9 isolates tolerance for corn damage from geese for those producers who attempted to prevent geese damage. The median willingness to tolerate is about $1,000 per year lower for those who attempted to prevent damage than those farmers who did not take preventative actions.

Implications

The use of agricultural lands by wildlife for habitat and food often results in yield losses 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 that explicitly recognize and model agricultural producers' tolerance of wildlife damage tolerance, or recognize the implications of tolerance in developing an appropriate welfare measure of crop losses from wildlife.

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 sub-optimal levels of wildlife, prevention activities 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 prevention 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.

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

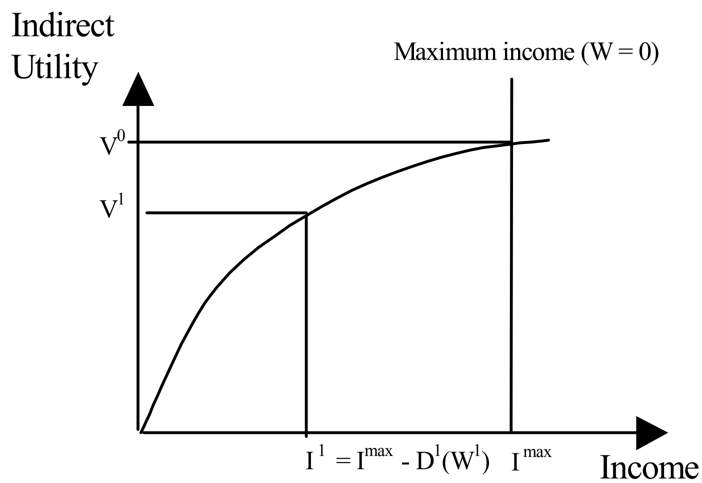


Figure 2 Marginal Utility of Income and Marginal Utility of Wildlife Use Benefits

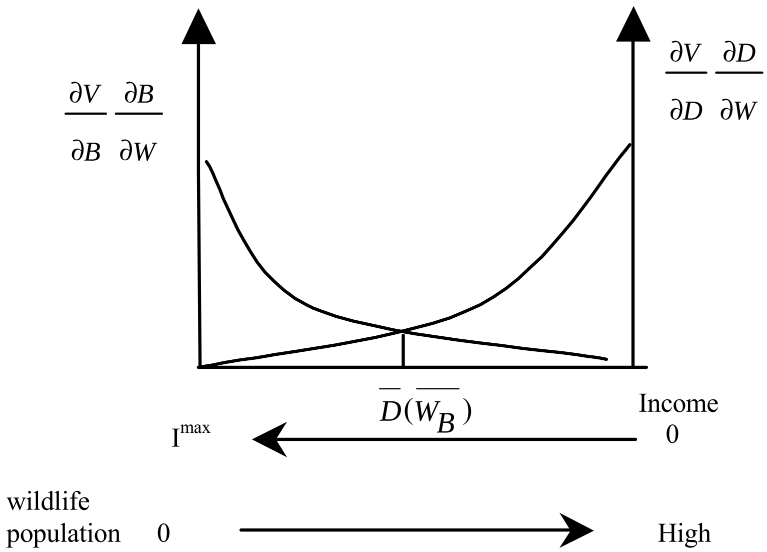


Figure 3 Maximum Willingness to Tolerate Damage for Wildlife Use Benefits

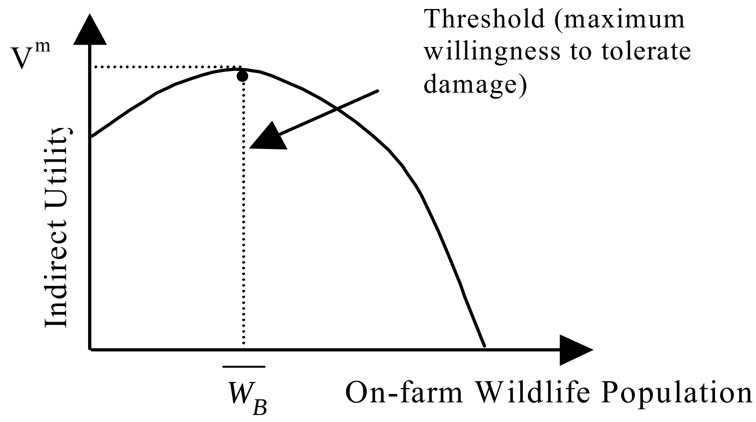


Figure 4 Marginal Utilities of Income and Wildlife Stewardship Provision

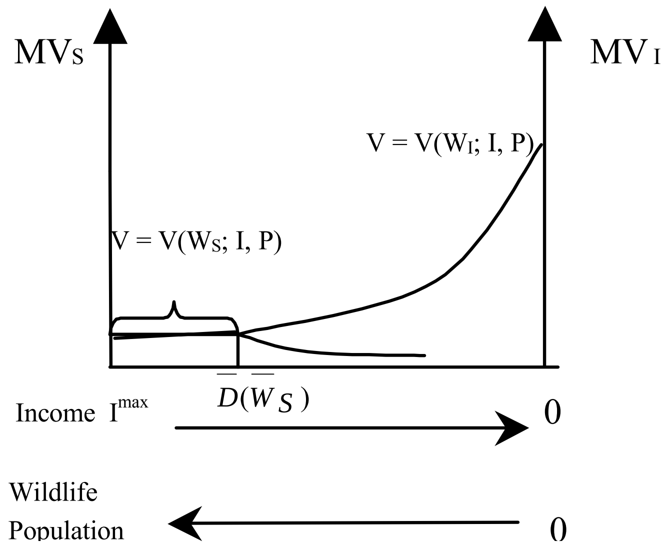


Figure 5 Maximum Willingness to Tolerate Damage for Stewardship Benefits

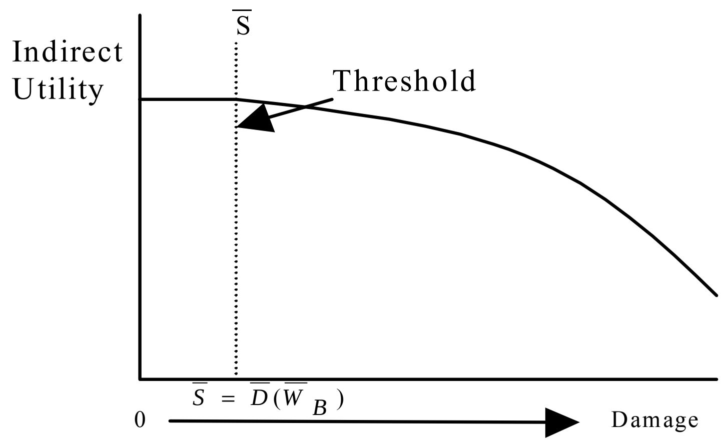


Figure 6   Welfare Loss from Damage

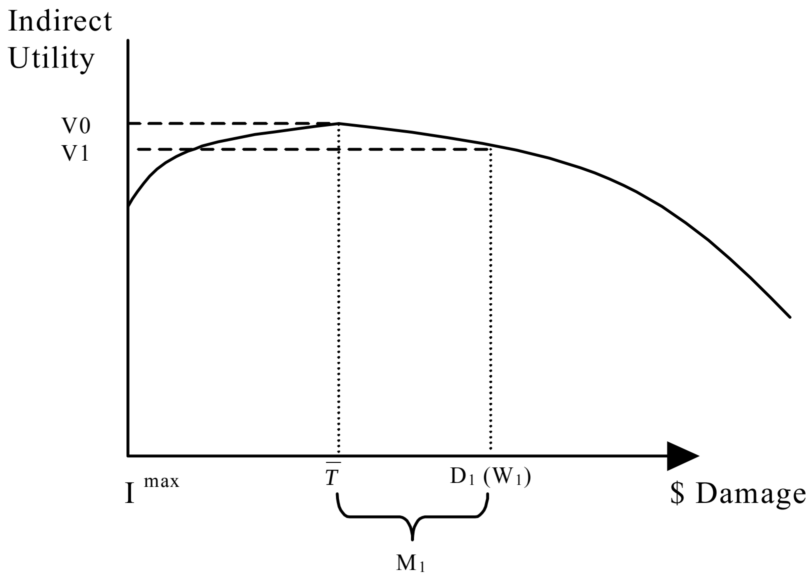


Figure 7 Ordered distribution of Yield Losses for Ontario Field Crop Producers

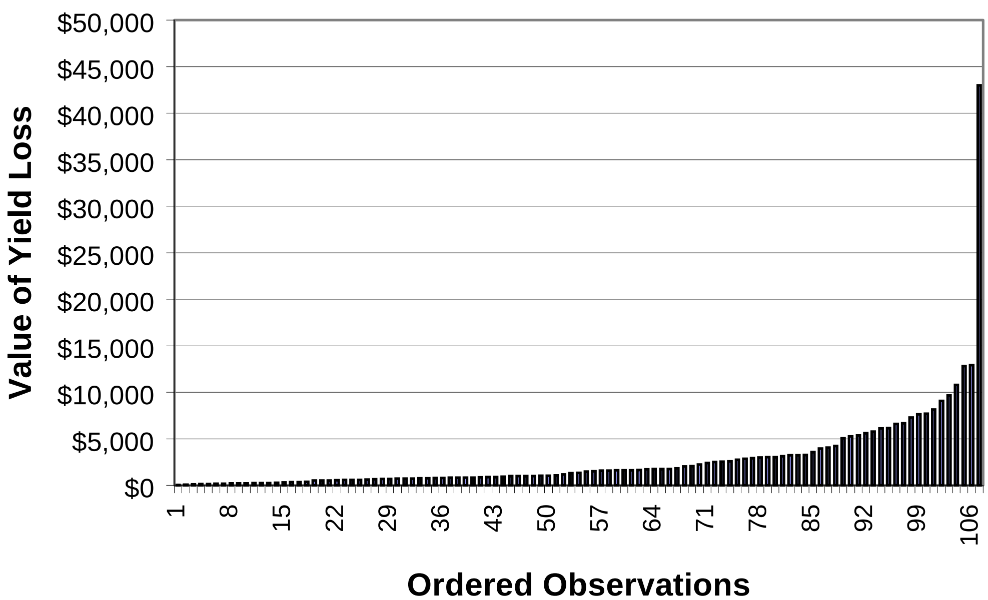


Table 1 Proportion of Producers Taking Preventative Action and Average Annual Investment

Producers taking preventative actions during last five years		Average annual investment for farms taking preventative actions in 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	Willing to Tolerate Damage
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

Variable	Definition	Variable Type
$ Damage	Value of yield loss by crop type and wildlife species type.	Continuous variable
Crop acreage	Number of acres specific to each crop type	Continuous variable
Public protected area	within 2 km proximity to public protected areas such as parks.	1= less than 2 km 0= further than 2 km
Private protected area	within 2 km proximity to private protected areas.	1= less than 2 km 0= further than 2 km
% Farm revenue	Percentage of household income from farming activities.	Continuous variable ranging between 1 and 100
% Crop revenue	Percentage of farm income from field crops.	Continuous variable ranging between 1 and 100
Crop Type: Corn Wheat Soybeans Forage/silage	Dummies for crop type Corn is base	0 or 1
Wildlife Species Raccoons Blackbirds Deer Geese	Dummies for wildlife species Raccoon is base	0 or 1
Perceived population	Respondent's perception of change in wildlife population over past 5 years.	1= Increased 0= not increased
Recreation value	Respondent rating of the importance of wildlife for recreational purposes	1= important 0= not important
Insect control value	Respondent rating of the importance of wildlife for the control of insects or rodents.	1= important 0= not important
Nonuse value	Respondent rating of the importance of wildlife for education and aesthetics.	1= important 0= not important
Prevention	Preventative action taken to control damage.	1= yes 0= no
Corn*Geese	Interaction effect	1 if both corn and geese, 0 otherwise
Soybean*Geese	Interaction effect	1 if both soy and geese, 0 otherwise
Prevent*Geese	Interaction effect	1 if both prevent and geese, 0 otherwise

Table 5 Results From the Random Effects Probit Model (N=1206)

	Coef.	(Std err)	Prob
$ Damage	-0.0014	(0.0002)	0.000
Crop Acreage	0.0041	(0.0013)	0.002
Public protected area	-0.4892	(0.3738)	0.191
Private protected area	-0.3573	(0.3550)	0.314
% Farm revenue	0.0063	(0.0052)	0.229
% Crop revenue	-0.0081	(0.0051)	0.113
Forage/silage	0.2020	(0.3941)	0.608
Soybean	0.1355	(0.4043)	0.737
Wheat	0.3535	(0.4321)	0.413
Blackbirds	0.6201	(0.3161)	0.050
Deer	0.7105	(0.2864)	0.013
Geese	2.1230	(0.5425)	0.000
Perceived Population	-0.8741	(0.2967)	0.003
Recreation value	-0.5557	(0.3198)	0.082
Insect control value	-0.0453	(0.4235)	0.915
Nonuse value	0.6345	(0.3465)	0.067
Abate	-1.0889	(0.2801)	0.000
Corn*Geese	0.4098	(0.1663)	0.014
Abate*Geese	-1.5469	(0.6825)	0.023
Constant	2.1208	(0.7264)	0.004
Log likelihood	-171.96		
Rho	0.5637		

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

	Blackbirds	Deer	Raccoons	Geese
Wheat	$1,376	$1,440	$935	$2,417
Soybean	$1,221	$1,285	$779	$2,262
Corn	$1,124	$1,189	$683	$2,457
Forage/Silage	$1,268	$1,332	$827	$2,309

Table : Maximum WTT Damage from Geese by abatement efforts over the previous 5 years

	Did not abate during previous 5 years	Did abate during previous 5 years
Wheat	$2,445	$1,345
Soybean	$2,290	$1,189
Corn	$2,485	$1,385
Forage/silage	$2,338	$1,237

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

	Yield Loss	Welfare Loss (Base WTT)	Welfare Loss (Base +20%)	Welfare Loss (Base – 20%)
Corn	$145,135.14	$72,314.36	$64,860.64	$81,162.12
Forage/Silage	$60,183.94	$40,342.68	$38,869.08	$42,706.58
Soybean	$28,677.04	$10,328.76	$8,831.76	$11,825.76
Wheat	$4,197.81	$0.00	$0.00	$0.00
Total	**$238,193.94**	**$122,985.80**	**$112,561.48**	**$135,694.46**

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	$8,910,070.52	$7,991,675.19	$10,000,229.73
Soybeans	$4,673,859.16	$1,683,408.25	$1,175,292.04	$1,927,393.21

Figure 8 Willingness to Tolerate Crop Damages to Corn by Wildlife Species

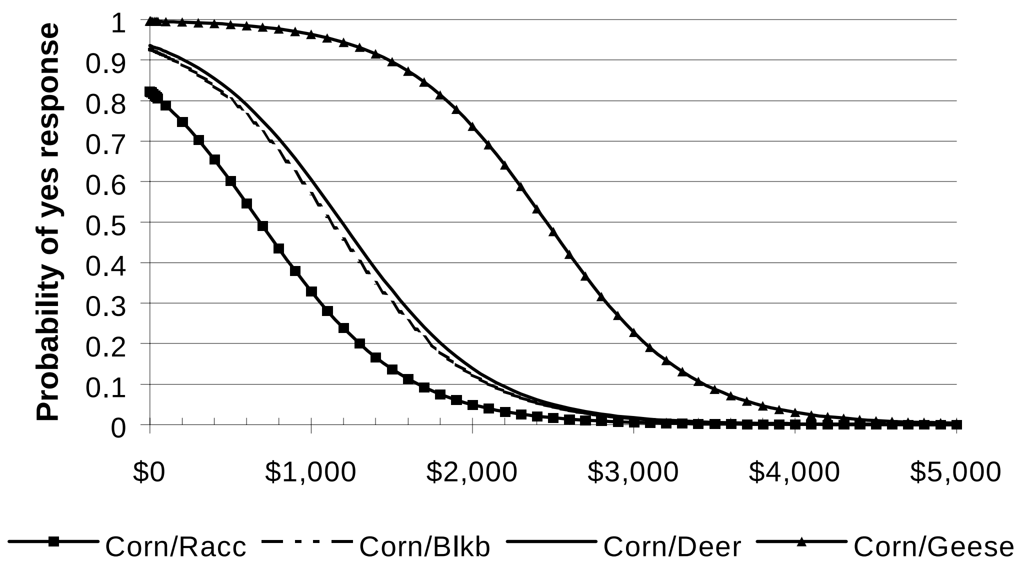
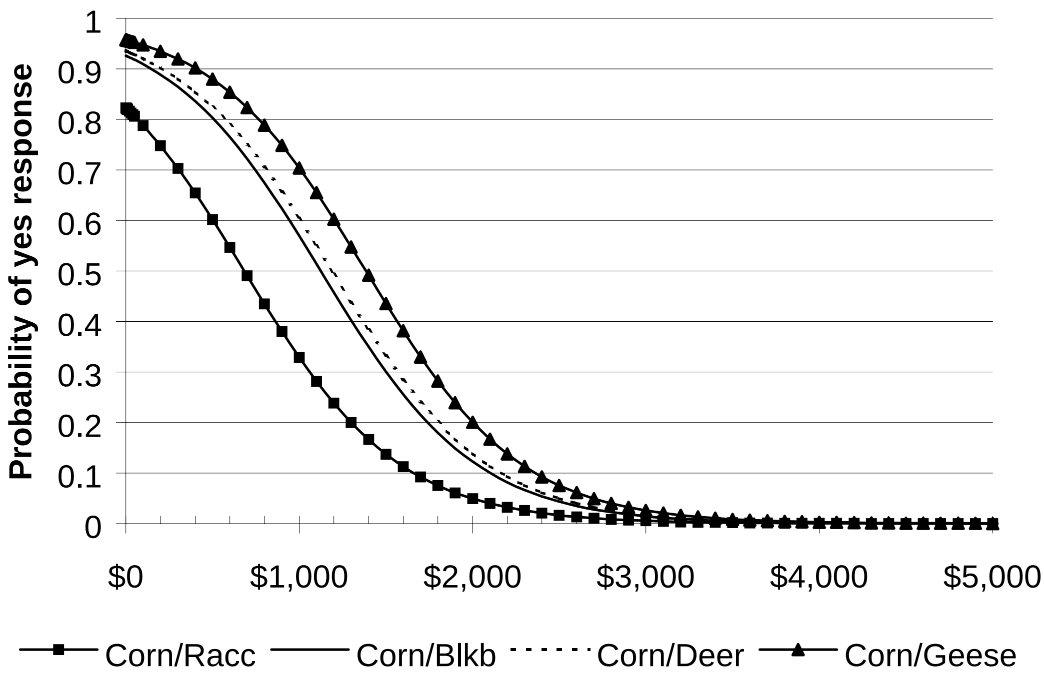


Figure 9: Willingness to Tolerate Corn Losses
Sensitivity to abate*geese



Appendix A:
Example of the survey question used to elicit the dependent variable

The survey was organized by sections that pertained to individual wildlife species. Participants were asked about both positive and negative aspects of wildlife presence. They were asked to estimate the % yield loss, by crop type, at time of harvest that they believed was attributable to the wildlife species in question. They were not asked to apply a dollar value to this loss. Rather, the researchers used the respondents total acreage, along with county data for expected crop yields to convert the % loss to crop units. The number of units lost were then multiplied by the market price for that cropt type. Thus, for the empirical model, the damage estimate was in dollar units, while the question below was posed in terms of the % yield losses by species and crop type.

For the section that dealt with Canada geese presence on private lands, the tolerance question read as follows:

How would you rate the losses by *geese* to your field crops in 1998?

	Tolerable	Not Tolerable
Corn	❑	❑
Soybeans	❑	❑
Wheat	❑	❑
Grain Silage	❑	❑
Forages	❑	❑

Endnotes

[1] 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. 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; USDA, 1993).

[2] 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 prevention assistance is preferable to compensation programs. The province does not currently have a wildlife damage policy.

[3] The list of Ontario producers is privately owned by the Angus Reid Group, which gathers data for research purposes.

[4] 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).