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Net Economic Value of a Deer - Ritz and Ready

Evaluating the Net Economic Value of a Deer in Pennsylvania

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* The authors are grateful to Gary San Julian for his helpful comments and suggestions.

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Abstract

The marginal net economic value of a one-animal change in the Pennsylvania deer population is estimated. Benefits from a larger deer population include hunting values and wildlife viewing values. Costs from a larger deer population include deer-vehicle accidents, increased incidence of Lyme Disease, and browsing damage to residential plantings, agricultural crops, and forests. The total economic benefit of a one-deer increase is $98-$223, while the total economic cost is $150-$232. No single category of benefits or costs dominates the analysis.

Key words: deer, deer-vehicle collisions, wildlife damage, wildlife values, Lyme disease, browsing, crop damage, human-wildlife interactions

Overview

Populations of white-tailed deer in the Mid-Atlantic, Northeastern and Midwestern states have increased steadily, and in many states dramatically, over the last 50 years, as a result of effective harvest management, increases in forested acreage, and a lack of natural predators. While many hunters welcome high population densities, and the consequently high hunting success rates, others are concerned that high densities are resulting both in damage to the forest ecosystem and in poor deer quality. Game managers are also under increasing pressure to consider non-hunting impacts of the deer population. It is commonly argued that deer populations now exceed the "cultural carrying capacity" of the habitat - a loosely-defined term that can be thought of as the population size that the community is willing to put up with.

Another approach to setting deer population targets is to attempt to maximize the total economic value, or benefit, of the various services provided by the deer stock, net of damages caused by the stock. The population (stock) of deer in an area generates both positive and negative services (benefits and costs). Positive services would include both harvest and wildlife viewing. Negative services would include crop damages, damages to ornamental plantings, lost future timber harvests due to browsing of tree seedlings, deer-vehicle collisions, and the spread of Lyme disease. A cost-benefit analysis of the deer population estimates the monetary value of each of these various positive and negative services and combines them into one measure of the net benefit to society from the deer stock.

This analysis can be done either using total benefits and costs, or using marginal benefits and costs. The top panel of Figure 1 shows how benefits and costs might vary as deer density varies. The middle panel of Figure 1 shows the net benefit (benefit minus cost) generated by the deer stock, as a function of the size of the stock. For any deer stock smaller than D_{zero}, the deer stock generates positive net benefits to society. For deer stocks larger than D_{zero}, the damages are larger than the benefits, and the stock generates negative net benefits to society. If a cost-benefit analysis shows that the total cost generated by the deer stock is larger than the total benefit, then we know that the deer stock exceeds D_{zero}.

The net social benefit generated by the deer stock is highest where the marginal benefit to society from having an additional deer in the stock is equal to the marginal cost to society of having that additional deer. In Figure 1, this occurs at D_{opt}. The second approach to conducting a cost benefit analysis is, then, to estimate the marginal benefit and cost from an additional deer. If that marginal benefit is less than the marginal cost, then we know that the deer stock exceeds D_{opt}.

Several studies have estimated specific categories of costs and benefits from deer. Many of these studies are reviewed in this paper. Roach, et al. (1996) combined several categories of costs and benefits as part of a policy analysis for a specific deer management issue. Their analysis did not include several important categories of benefits and costs, however. Conover (1997a) analyzed total economic costs and benefits of deer for the entire United States, and concluded that the benefits from deer exceed the costs by a wide margin (that is, the deer stock for the U.S. is smaller than D_{zero} in Figure 1). This paper takes Conover's analysis one step further. We estimate the marginal benefit and cost of the deer stock, to determine whether that stock exceeds D_{opt}. This is done for a smaller geographic area -- the State of Pennsylvania. Marginal values of deer likely differ dramatically from state to state, making a national analysis inappropriate.

Pennsylvania is currently a good case study for this type of analysis. The Pennsylvania Game Commission has advocated a shift in how deer are managed, incorporating the concepts collectively referred to as “quality deer management.” This change would involve 1) a decrease in the total number of deer in the state, 2) an increase in the proportion of deer taken that are antlerless, and 3) protection of young male deer in order to increase the supply of better quality bucks. Put in simple terms, the goals of these changes are increased ecosystem health and increased deer quality, at the cost of deer quantity. An estimate of the marginal net benefit of a deer is therefore of particular interest in Pennsylvania.

One limitation of our analysis is that it focuses on the benefits and costs associated with the change in the quantity of deer in Pennsylvania, but will not consider the impacts on hunters associated with any potential change in deer quality. Still, the estimates derived in this study are a useful first step in incorporating diverse impacts into a comprehensive framework for evaluating alternative deer management programs at the state level with the current information available. Furthermore, by attempting to put dollar values on the identified costs and benefits of deer in Pennsylvania, this study provides useful details about where further information is needed and where current estimates are the weakest.

Benefits of deer

The benefits of maintaining a high deer population include the value that hunters place on hunting success and the benefits that hunters and non-hunters enjoy from viewing and photographing deer. Non-hunters, especially those that participate in hunting-related activities, may also receive benefits from hunting (Stedman and Decker 1996), but estimates of this value do not exist. The size of the benefit generated by the deer population depends critically on the population density of the deer. In recent years in Pennsylvania, the pre-hunting season population has been estimated at 1.4 million animals. While the population density per square mile varies widely throughout the state, on average, there are 37 deer per square mile of undeveloped land (farmland and forested land) in the state. This is slightly higher than the density in the neighboring states of Maryland and New York (see Table 1).

Hunter Values

This section estimates the economic value to hunters of the increase in expected hunting success that would occur as the result of a one-animal increase in the deer population in Pennsylvania. This marginal value is calculated as the increase in the probability of taking a deer, times an estimate of the marginal value to hunters of taking one additional deer. This latter value is defined as the amount of money hunters would be willing to pay (WTP) in order to achieve increased hunting success, and is most often estimated using a survey-based method called the contingent valuation method (CVM).

A significant portion of the Pennsylvania population takes part in deer hunting. From 1996 to 1998, the number of general license sales in Pennsylvania remained relatively constant at just over one million. By way of comparison, the total population of Pennsylvania is about 12 million people. In 1998, exactly 1,071,205 licenses were sold, though this figure includes non-resident hunters (Pennsylvania Game Commission 1998). It is not known what proportion of these licensees actually hunted during the year or how many others hunted without a license, so the license sales number is used as the best approximation for the number of hunters, both resident and nonresident. In 1998, the total Pennsylvania harvest of antlered and antlerless deer was 377,489 (Pennsylvania Game Commission 1999). The hunting success rate was then 0.35 (about 1 deer bagged for every three hunters), while the harvest rate was 0.27 (just over one-fourth of the pre-hunting season deer population was removed during the season).

We assume that an increase in the deer population in Pennsylvania would result in a proportionate increase in the number of deer harvested. Several studies have estimated hunters' WTP to take additional deer. Loomis, Creel, and Cooper (1989) estimated a WTP for the legal right to hunt an additional average buck at $165 in a California hunting zone. California licenses are distributed through a lottery and those who are chosen purchase a license for one deer (Cooper 1993). The hunter success rate in California is 11%, so that the value of a harvested deer is $1500.

Mackenzie (1990) used conjoint analysis to estimate the WTP for several aspects of deer hunting trips in Delaware. The marginal valuation of a 1% increase in the probability of bagging a deer is found to be $6.84, so that the statistical value of a harvested deer is $684. Because the hunter success rate in Delaware (5-20%) is lower than in Pennsylvania, the marginal value of a deer is likely to be higher in Delaware than in Pennsylvania.

Lynch (1997) used responses to contingent valuation questions included in the U.S. Fish and Wildlife Service's Survey of Fishing, Hunting, and Wildlife Associated Recreation to estimate the marginal value to hunters of increased hunting success. The marginal value of taking one additional deer was found to be $111 nationwide, and $316 for Maryland. The U.S. Fish and Wildlife Service (1998a) estimated a similar value of $372, using the same survey data, for the Northeast and Mid Atlantic Region, an area that includes Pennsylvania.

These estimates are summarized in Table 2. The values for Maryland and for the Northeast and Mid-Atlantic Region are similar, and are likely the best estimates for use in Pennsylvania. Hunter success rates, shown in Table 1, are higher in Maryland; possibly the direct result of a greater number of kills allowed per hunter. The marginal value of bagging an additional deer might therefore be lower in Maryland than in Pennsylvania. The value estimated for Maryland is treated here as a lower-bound estimate for Pennsylvania. The higher value of $372 for the larger region including Pennsylvania and Maryland is used as an upper-bound estimate. These per-deer values are then inflated to 1999 dollars and multiplied by the average harvest rate for the state, 0.27. The resulting value to hunters of an additional deer in Pennsylvania is then $91-$107 per deer.

Non-Consumptive Value

The non-consumptive value of deer includes the value of activities such as deer viewing and photographing. Unfortunately, available studies on non-consumptive benefits specifically from deer are few. This section develops an estimate of the amount that Pennsylvania residents would be willing to pay to increase the number of deer seen on trips taken to view wildlife. Benefits from seeing deer at other times are not included, as appropriate estimates of such values are not available. Non-consumptive values would logically also include non-use values such as existence value, but information on marginal existence values for deer is not available. It should be pointed out that the marginal existence value for an increase in the deer population could be positive or negative, depending on residents' perceptions of whether there are "too many" deer.

Estimates of viewing values for deer are in short supply. Shafer, Carline, Guldin and Cordell (1993) used CVM to estimate values for trips to view elk in Pennsylvania. The elk herd is very small and concentrated in a small geographic area. The data only allowed estimation of average willingness to pay, estimated at $20.43 per trip. Corresponding values for deer in Pennsylvania would likely be lower, since deer are much more abundant and more evenly distributed throughout the state.

In California, Loomis, Updike and Unkel (1989) used contingent valuation to estimate the value of viewing deer during outdoor recreation trips. For the state as a whole, the value for the general public was $11 per trip taken where deer were seen and $15 for those trips that were taken specifically to view deer. In the so-called "X" zones, the hunting areas in the northeast corner of the state and along the east side of the Sierra Nevada Mountains, the value per trip taken where deer were seen was much higher at $19.

Loomis, Updike and Unkel (1989) also found that the value per trip increased as the number of deer seen increased. In the X zones, the $19 value per trip corresponded to a trip where six deer were seen. If the number of deer seen were to double, the value would increase by $7 to a total of $26. Assuming a constant marginal WTP for each percent increase in the number of deer seen, we calculate that a 1% increase in the number of deer seen is valued at $0.10 per trip. Using statewide numbers gives a much lower estimate of the marginal value of additional deer seen. Statewide, the value of a trip increases from \$11.00 to \$11.40, resulting in a marginal value per 1% increase in deer seen of \$0.0057.

In order to apply these results to Pennsylvania, it is assumed that the number of deer seen is linearly related to deer density. The marginal willingness to pay for a one percent increase in deer population would then be equal to the marginal willingness to pay for a one percent increase in the number of deer seen per trip. The resulting non-consumptive wildlife viewing benefit is $\$7.1x10^{-6}$ per viewing trip, using the X zone estimate, and $\$4.1x10^{-7}$ using the statewide estimate. Although small, these values are important when applied to the 11,114,000 trips away from home for the purpose of wildlife viewing taken by Pennsylvanians (U.S Fish and Wildlife Service 1998b). The estimated range for the non-consumptive value of an additional deer updated to 1999 dollars is then \$7-\$116.

Costs of deer

The costs of maintaining a large deer population in Pennsylvania include the damage caused by browsing on crops, commercial timber resources, and ornamental plantings, damages from deer-vehicle collisions, and possibly damages associated with increased incidence of Lyme disease.

Lyme Disease

Borrelia burgdorgeri, the bacteria that causes Lyme disease is transmitted to humans through the deer tick, *Ixodes dammini*. The deer tick is commonly found in the Northeastern and Midwestern United States and is carried by white-tailed deer among other hosts. Lyme disease is now the leading cause of vector-borne infectious illness in the U.S. Individuals thought to be at greatest risk are those who hold outdoor occupations or participate in outdoor recreational activities that are located near wooded areas or overgrown brush (CDC 1999b).

The risk to humans of contacting Lyme disease depends on the density of deer ticks. Duffy, et al. (1994) report a correlation coefficient of 0.45 for the relationship between tick numbers and cases of human Lyme disease reported in adjacent areas on Long Island. A correlation of 0.63 has also been found to link the percent of deer examined which hosted at least one deer tick and the number of Lyme disease cases per 100,000 people in a sample from five states, including Pennsylvania (Daniels, et al. 1993b). The density of deer ticks in turn depends, in part, on the density of deer. (Wilson, et al. 1988). In part of Massachusetts, a management plan was implemented to gradually reduce the deer population from about 350 in 1983 to about 60 in 1991 using controlled shooting. This deer removal resulted in a 50% reduction in the abundance of deer ticks (Deblinger, et al. 1993). Unfortunately, the change in human Lyme Disease cases was not reported. Other studies have shown that total exclusion of deer from an area can lead to large reductions in infected ticks, but will not completely eliminate the risk (Daniels, et al. 1993a, Stafford 1993). These studies, taken together, indicate that there is a positive relationship between deer populations and cases of human Lyme disease, though it is not known whether the relationship is strictly proportional.

Pennsylvania ranked third among states in reported cases of Lyme disease in 1998 and in total cases over the prior decade. Reported cases (see Table 3) increased from 626 in 1989 to 2,760 in 1998, though it is thought that the actual incidence is grossly underreported (CDC 1999a). While the number of cases in Pennsylvania and nearby states with Lyme disease endemic areas appear to have peaked in 1996, there is no clear indication of what the future number of cases will be.

Meltzer, et al. (1999) estimated the cost of illness from a case of Lyme disease. Cost of illness includes treatment costs and lost work productivity, but does not include a measure of pain and suffering from the disease. Cost of illness per case figures, from 1996, differ depending on whether the case is detected early. For cases that are detected early, the average cost of illness was estimated at $161 per case. Between 60-90% of cases are detected early. Cases not detected early are broken down into three case types: cardiac, arthritic, and neurologic, in increasing order of severity. The cost of illness estimates for these three sequelae are, respectively, $6,845, $34,354 and $61,243 per case.

Assuming that Pennsylvania continues to experience 2,760 cases per year, the total costs of Lyme disease in Pennsylvania can be calculated. Assuming that 90% of cases are detected early, 8% are cardiac, 2% are arthritic, and none are neurologic, the total cost of illness for Lyme disease in Pennsylvania would be $3.8 million per year. In contrast, assuming that only 60% are detected early, 25% are late cardiac cases, 10% are arthritic and 5% are neurologic, the estimated cost of illness would be $22.9 million per year. Neither of these estimates accounts for cases that are never detected.

An additional component of the social cost of illness is the pain and suffering caused by the disease. One measure of pain and suffering is the number of quality adjusted life years (QALY) lost per case. QALY's measure the duration and severity of an illness. The Institute of Medicine (1999) found an average QALY loss of 0.016 years per Lyme disease case. This estimate is not broken out by severity of illness. Applying their decision criterion of $100,000 per QALY to all 2,760 cases gives an estimated value of pain and suffering of $4.5 million per year. Adding this estimate of pain and suffering costs to the cost of illness estimates gives a total cost from Lyme disease of $8.3 to $27.4 million (in 1999 $) per year.

Absent better information about the exact relationship between changes in the deer population and incidence of Lyme disease, we assume that the relationship is strictly proportional. Using the high and low estimates of cost of illness generated above, the average cost from Lyme disease ranges from $7 to $21 per deer.

Deer-Vehicle Collisions

More than 40,000 dead deer are removed from Pennsylvania highways annually. The incidence of dead deer increased by 74% between 1982 and 1990, from 24,648 to 43,002 (Roman and Bissonette 1996). These counts include only those deer that are reported to the Pennsylvania Game Commission, but as many as one third of the actual total may go unreported (Rue 1989, p.430). It is also not clear how many deer are hit, but do not die, or die some distance from the roadway.

The damage resulting from these collisions includes property damage, injury, and even human fatalities. The Erie Insurance Group, Pennsylvania's second largest auto insurer, reports an average cost of $1,500 dollars in damage resulting from deer-vehicle collisions (Erie 1998). Conover, et al. (1995), using data from Michigan, New York, Pennsylvania, Utah, and West Virginia, estimate an average damage cost of $1,577 in 1993 dollars per incident. These estimates are in line with the $1,000-2,000 per collision estimate reported by the USDA Forest Service (1994). The Pennsylvania Game Commission estimates over 40,000 collisions and over $80 million in resulting losses in the state each year (Alt 1999, DuBrock 1999). None of these estimates include losses due to injuries and fatalities.

The Pennsylvania Department of Transportation defines reportable crashes as one where an injury or fatality occurs or at least one vehicle on the scene must be towed. There were 2,387 reportable accidents in which the first object struck was a deer in Pennsylvania in 1999. This represents an increase of nearly 70% from 1990. Seven deaths and 469 injuries resulted from 1,598 crashes in 1992 (PA Department of Transportation 2000). Comparable figures for later years are not available and these figures do not include accidents occurring as the result of actions taken to avoid hitting a deer or those with minor injuries, not serious enough to report.

It is assumed that the average insurance damage claim is from the type of accident included in the Game Commission's deer collision reports. An average cost of $1,500 in property damage per accident applied to approximately 40,000 accidents per year results in $60 million total property damage. To calculate the social costs associated with human fatalities, the EPA's estimate of the value of a statistical life, $5.9 million, is used (EPA 1999). Assuming that the incidence of injury and fatality reported is the same as in 1992 yields a social cost from fatalities of $41.3 million per year. If the rate of injuries and fatalities has increased at the same rate that the total number of accidents has increased, this estimate would be about 50% higher. The total damage estimate, including property damages and social costs from fatalities inflated to 1999 dollars, is then $105.4 million. This estimate does not include pain and suffering of the injured accident victims, but those costs are likely small relative to the total. Using this estimate as an upper bound, and the Game Commission's total cost estimate of $80 million as a lower bound, the range of the average cost of collisions with vehicles is $52-$75 per deer.

Damage to Homeowners and Nurseries

As residential and commercial development continues to expand into rural areas with high deer populations, there is increased potential for damage caused by deer to trees, shrubs, gardens, and flowers purchased by homeowners and produced by nurseries. The resulting expense includes the value of the lost plants as well as the cost and time taken for preventative measures.

In a survey conducted in 10 of the 100 largest metropolitan areas, a mean damage of $64, mean prevention expenditure of $32, and mean time expenditure of 7.2 hours were estimated for the 61% of the sample reporting wildlife damage (Conover 1997b). This study found, however, that only 4% of the households surveyed reported damage caused by deer. Sayre, et al. (1992) surveyed nurseries and homeowners in Southeastern New York (SENY) and Western New York (WNY). Two-thirds of nursery producers and 32% of homeowners reported deer damage in SENY. In WNY, deer damage was less prevalent, affecting 61% of producers and 17% of homeowners. The median loss to homeowners in SENY was $200 (n=26) and $90 (n=22) in WNY. Producers in SENY reported 6% of production values damaged at a median value of $3000 (n=24), while those in WNY reported 0.6% damaged with a median value of $1,800 (n=16). In suburban Islip, New York, the cost per deer is as high as $1300 for damage to shrubs and gardens and preventative measures (Decker and Gavin 1987). It should be noted that these studies were done in suburban areas where the potential for residential deer damage is the greatest and the sample sizes of the surveys were small.

There were approximately 2.9 million metropolitan and 593,000 nonmetropolitan owner occupied housing units in Pennsylvania in 1990 (U.S. Census Bureau 1990). Assuming 4% of metropolitan households sustain deer damage gives an estimated 116,000 metropolitan households with deer damage. Inflating to 1999 dollars and using the Conover (1997b) estimate of damage per household for metropolitan households, and the WNY estimate of the proportion of nonmetropolitan households with damage and damage costs per household, gives a total estimated damage of $25.7 million per year. Substituting the SENY information for WNY gives an estimated total damage of $66.5 million per year.

In addition, there are 2,772 nurseries, primarily growers, registered with the Pennsylvania Department of Agriculture's Bureau of Plant Industry (Walter Blosser, personal communication). Inflating to 1999 dollars and applying the Sayre et al. (1992) SENY and WNY nursery damage estimates to these nurseries yields additional damages ranging from 4.3 to 7.9 million. The average cost per deer to both homeowners and nurseries is then estimated at between $21 and $53.

Crop Damage

Estimates of deer damage to commercial crops are developed here for fruit crops (apples and grapes), grains (corn, soybeans, and wheat), and alfalfa and cabbage.

In the Hudson River Valley, where average deer densities are estimated at over 15 deer/mi^2, the estimated average percent of crops lost to deer was 3.2% for fruit growers and 3.5% for other crops (Decker and Brown 1982). The fruit growers' average damages of $3,000 were three times that of other farmers and they sustained nine times as much damage on an area basis.

Estimates of the total damage to apple and grape crops from wildlife are available for Pennsylvania (Stout, E. 1999). For both crops, the cost to growers (value of production lost to wildlife damage plus expenditures on damage prevention) was between 1% and 2% of the total value of the harvest. The total cost to growers of both crops was estimated to be $0.9 million. Damages are not broken down by type of wildlife, but nationally, deer are the second most frequently reported wildlife causing damage to apples, with 14% of these growers reporting damage. Fewer grape grower, 8%, reported deer damage to crops (Stout, E. 1999). The percentage of the damage caused by deer cannot be determined, but even if deer were responsible for all of this damage, the cost is minor compared to the estimated damages to field crops in the state.

A survey of Pennsylvania farmers by Tzilkowski, et al. (1997) found that 68.4% report deer as the primary cause of damage to alfalfa crops. Although somewhat dated, Palmer, et al. (1982) examined damage to alfalfa crops in Pennsylvania through surveys and experimental research. Of those surveyed in 1979, 21% reported deer damage to alfalfa crops at an average loss of $592. Experiment results found a loss of approximately one fifth of the crop was attributable to deer each year. This does not include damage to the value of the future crop due to increased growth of grasses. The average deer density for the region at the time, approximately 28 deer/mi^2 was lower than the current density. In 1998, 700,000 acres in Pennsylvania were harvested for alfalfa with a yield per acre of 2.8 tons (PA Department of Agriculture 1999). Assuming 21% of the harvested acres, or 147,000 acres, sustain losses of one fifth of the yield per acre, or 0.56 tons, the total value loss to alfalfa crops in Pennsylvania is approximately $11.1 million (in 1999 $).

More recently, McNew and Curtis (1997) estimated deer damage to soybean, corn, and wheat crops in Maryland. A 1997 survey of grain farmers found deer responsible for losses of 12.6%, 6.7%, and 2.7% to yields of soybean, corn, and wheat respectively. Using farmer estimates of the number of deer on their farms, linear regression results indicated that a 10% increase in the deer population would add an additional $1.2 million (3% increase) in damage onto the initial $37.9 million. The calculated deer population elasticities of crop damage (the percent loss in crop yields as a result of a one percent increase in deer density) for soybeans, corn, and wheat are 0.3, 0.34, and 0.65 respectively. Tzilkowski et al. (1997) found a similar loss to corn from deer, 6.4%, for Pennsylvania, but do not include estimates of the local deer population in their report. The Pennsylvania report also estimates total 1995 deer damage to cabbage crops at $639,000 from field sampling.

Applying the Maryland results to current corn, soybean, and wheat production in Pennsylvania gives an estimate of $26.4 million (in 1999 $) of total crop damage. However, the marginal damage of a deer herd increase is much lower than the average damage. An increase of 1% in the deer population would cause an additional $91,200 in crop losses for these three crops. The total damage to grains, alfalfa, and cabbage are then $38.2 million (in 1999 $) per year. Using the marginal damage for grains developed above, but assuming proportionality for alfalfa and cabbage, the additional damage per deer is estimated to be $15.

In contrast, DuBrock (1999) estimates the total damage to all crops from wildlife to be greater than $70 million per year, with 75-80% attributable to deer. Thus, deer may be responsible for total crop damage worth at least $52.5 million in Pennsylvania. Using this estimate, and assuming proportionality, gives an estimated crop damage per deer of $38. The result is a range of $15-$38 for the average cost per deer of crop damage.

Damage to Timber Industry, Forests, and Ecosystems

Damages caused by deer to forests and forest ecosystems are even more difficult to assess. Deer browsing causes delays in harvesting time for forests and increases the rotation age. Deer browsing allows fern cover to increase interfering with the development of new seedlings and thus, the natural process of tree regeneration (Horsley and Marquis 1982). Deer also alter species compositions to concentrations of lower value timber (Marquis and Brenneman 1981). In addition to all this, there are implications for the habitats of other animals.

A study by Marquis (1981) of the U.S. Forest Service in Pennsylvania is the most complete effort to place a dollar value on timber damages due to deer. Fenced enclosures were constructed in cutover areas 9-22 years earlier. This study compares forest composition and growth in fenced and unfenced areas and estimates deer damages of $13/acre per year for Allegheny hardwood forests. More recent published estimates are simply updates of that estimate, using current costs of prevention and timber prices. The updated figure for the entire state is $75 million (Stout S. 1999, DuBrock 1999).

Do forest damages increase proportionately with deer population? McCullough (1952) measured the damage to experimental forests in Pennsylvania exposed to different levels of deer browsing pressure. Variables measured included the length of the forest rotation period, the number of trees lost, and changes in species composition under high densities (18 deer/mi^2) and low densities (9 deer/mi^2). Low deer density plots were left with 0-7% of stems heavily browsed and 5-44% lightly browsed resulting in $0-0.87 per acre of total damage. In highly populated plots, 25-78% was heavily browsed while 14-50% was lightly browsed resulting in $4.23-23.19 total damage per acre. The range of estimates included different types of forest and different aged forest stands.

Tilghman (1989) documented changes in the Allegheny hardwood forests of Pennsylvania at various deer densities over a five-year period. Four sites were used with similar overstory, but different understory representing different forest regeneration stages. Pens simulating populations of 0, 10, 20, 40, and 80 deer/mi^2 were used. Differences were seen in height of growth, species composition, tree density, regeneration, and ground cover. The most striking result was the effect on the average height of seedlings. Seedlings in the low-density plots were almost twice as high as the highest density plot. The largest marginal changes occurred from 20 to 40 deer/mi^2 in clear cut and thinned areas. Tree species sensitive to deer browsing also experienced significant reductions in seedling numbers at the highest two deer densities in clearcut plots. Changes in species composition were also evident and exemplified by 75% black cherry in highest deer density plots and only 18% black cherry in plots without deer. Groundcover by ferns was also found to increase in high density plots. In clearcut and thinned stands, significant effects were seen at the 40 and 80 deer/ha densities, but the effects of deer on uncut stands were only significant at the highest density. These results suggest that the marginal impact of deer populations is highest at densities similar to those found in Pennsylvania today, and that the marginal damage is likely higher than the average damage that would be calculated assuming proportionality.

There are, of course, other problems created by these effects on forests. Less diversified forests increase the potential damage of an outbreak of an insect or disease epidemic (Tilghman 1989). Habitats of other species are also affected although this is difficult to measure. Reduction of density and presence of many plant and animal species due to deer have been documented (DeCalesta 1997). Still, the best available estimate of the total damage to Pennsylvania forests is the updated Marquis estimate of $75 million per year. While it likely understates the marginal damage from a change in the deer population, we assume proportionality in determining the average damage per deer, and find that the average cost per deer of forest damage is $55 (in 1999 $).

Conclusion

The estimated marginal impacts of a one-deer increase in the Pennsylvania deer population are summarized in Table 4. While this review represents the most comprehensive analysis of the net marginal value of a deer performed to date, and gives an idea of the relative importance of different costs and benefits stemming from the deer population in Pennsylvania. It also focuses attention on areas where cost and benefit information is deficient and potentially a significant contribution, such as Lyme disease and forest damage.

Ranges are provided for some of the estimates in Table 4, where the benefit or cost estimate could be calculated under more than one set of assumptions, or where multiple estimates of the impact exist in the literature. However, those ranges are not intended to be confidence intervals around the estimates. We have made no attempt to generate estimates of the uncertainty associated with each figure presented in Table 4.

Interestingly, the impacts considered in this analysis are all of the same order of magnitude. No single impact dominates the analysis. Nor is there any impact that is small enough to be ignored. Finally, we cannot identify any of the listed impacts where we can say that sufficient information exists to generate a highly reliable estimate. Additional information is needed on each and every category of impact. Still, we would state that our estimates for the categories of wildlife viewing, Lyme Disease, and Forest Damages are somewhat less reliable than those for hunting, deer-vehicle collisions, and damage to crops. Those categories of impacts are most in need of additional research.

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Table 1. Deer population, density and hunting success in selected states.[a]

	PA	MD	NY
1999 Deer Population	1,4000,000	250,000	1,000,000
Deer Density (# deer/undeveloped mi^2)	37	32	25
Forest Deer Density (#deer/forested mi^2)	52.7	59.2	34.3
Hunter Success Rate (# killed/# hunters)	0.35	0.60	0.53

[a] References by state - MD: Sandt 1997, Lynch 1997, DNR 1998, Frieswyck and DiGiovanni 1988; PA: PGC 1998,1999 & 2000, Alerich 1993; NY: DEC 2000, Alerich and Drake 1995. Also USDA 1997.

Table 2. Estimates of WTP for deer harvest

Study	Location	Marginal WTP for one deer
Lynch (1997)	United States	$111
Lynch (1997)	Maryland	$316
USFWS (1998a)	Northeast and Mid-Atlantic	$372
Mackenzie (1990)	Delaware	$684
Loomis et al. (1989)	California	$1500

Table 3. Reported cases of Lyme disease[a]

State	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Pennsylvania	626	553	718	1173	1085	1438	1562	2812	2188	2760
Connecticut	774	704	1192	1760	1350	2030	1548	3104	2297	3434
New York	3224	3244	3944	3448	2818	5200	4438	5301	3327	4640
Rhode Island	415	101	142	275	272	471	345	534	442	789

[a] source: CDC 1999a

Table 4. Summary of marginal costs and benefits

Cost/Benefit Category	Benefit Per Deer	Cost Per Deer
Hunting	$91-$107	
Wildlife Viewing	$7-$116	
Lyme Disease		$7-$21
Deer-Vehicle Collisions		$52-$75
Residential Plantings		$21-$53
Crop Damages		$15-$38
Forest Damages		$55
Total	$98-$223	$150-$232

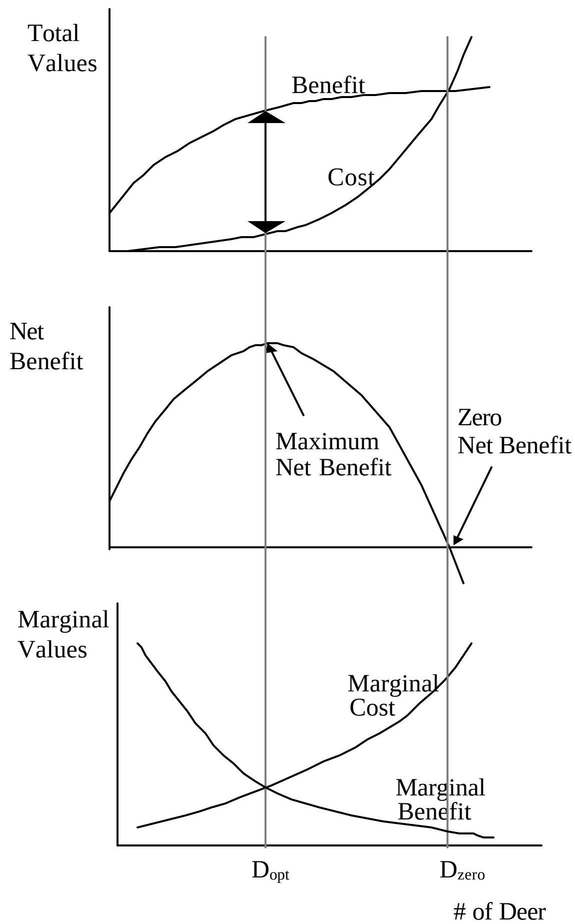

Figure 1. Illustration of the optimal deer population using marginal benefit-marginal cost analysis.

In addition, for some economies, such as Belgium or the Netherlands, the assumption of a small open economy with perfect capital mobility is a good one. Yet this assump-tionâ€”and thus the Mundellâ€"Fleming modelâ€”does not apply exactly to a large open economy such as the United States.Â Letâ€™s begin with the assumption of a small open economy with perfect capital mobility. As we saw in Chapter 5, this assumption means that the interest rate in this economy r is determined by the world interest rate r*. Mathematically, we can write this assumption as. r = r*. plus the net outflow of capital abroad. minus the net exports of goods and services. plus the government's budget deficit. minus foreign portfolio investment. plus the net outflow of capital abroad. National saving is the nation's income that is left after paying for current consumption and government purchases, that is: S = Y-C-G . This can be rewritten as S=I+NX , which can be further rewritten as S=I+NCO , since the value of net exports must be equal to the value of net capital outflow.Â If the value of a nation's imports exceeds the value of its exports, which of the following is NOT true? Net exports are negative. GDP is less than the sum of consumption, investment, and government purchases. Domestic investment is greater than national saving. Deer Farms Spend Heavily in Pennsylvania Pennsylvania s deer and elk farms put their money back into the Commonwealth, providing a source of economic development opportunity for rural areas as well as many small farming opportunities for more urban areas where open space preservation is important. $8,000,000 PA Deer Farms Spending, 2006 Nutritive Value of Meats (100 Grams) $6,000,000 Meat Fat (g) Cholesterol (mg) Calories (kcal) Protein (g) Venison Turkey Chicken Salmon Pork Lamb Beef $4,000,000 $2,000,000 Venison offers very low fat, cholesterol and calories, while also providing good protein Net present value (NPV) looks to assess the profitability of a given investment on the basis that a dollar in the future is not worth the same as a dollar today. Money loses value over time due to inflation. However, a dollar today can be invested and earn a return, making its future value possibly higher than a dollar received at the same point in the future. NPV seeks to determine the present value of future cash flows of an investment above the initial cost of the investment. The discount rate element of the NPV formula discounts the future cash flows to the present-day value.Â The internal rate of return (IRR) rule is a guideline for evaluating whether a project or investment is worth pursuing. more. Payback Period Definition. The economic criterion for these decisions should be the value of a change in the stock of the wildlife population compared to its cost. An estimate of such a value was made for the Oak Creek deer herd in Utah, using a household production function approach in an optimal control framework. The value of an additional deer in the herd was estimated to be approximately $40.00. View. Show abstract.Â Evaluating the net economic value of a deer in Pennsylvania. Unpublished 796 Manuscript. Non-point source pollution â€" A self-reporting mechanism.