DAMAGE ABATEMENT AND COMPENSATION PROGRAMS AS INCENTIVES FOR WILDLIFE MANAGEMENT ON PRIVATE LAND

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Abstract: Public damage abatement and compensation programs may be used to alter private incentives for damage abatement and habitat provision. A model is developed that explains the economic logic behind prevalent characteristics of public wildlife damage programs. The model is supported with an examination of a broad cross-section of wildlife agency policy and law. The model can be used by wildlife managers and policy makers as a conceptual framework for understanding the incentive effects of compensation and abatement policy.

Key Words: abatement, compensation, damage, incentives, management, wildlife.

Wildlife imposes costs on landowners in the form of crop damage, livestock depredation, and damage to a wide variety of other productive capital. Fifty-five percent of agricultural producers in the United States reported some level of wildlife damage in 1989, and total estimated damage for the country was as high as US$1.26 billion (Wywialowski 1994). Agricultural landowners provide much of the wildlife habitat throughout the United States and the world, and wildlife-inflicted property damage may provide incentives to reduce the quantity and quality of habitat on private land.

Most state wildlife agencies maintain some form of program to address wildlife damage to agricultural property (Lueck 1989, Lueck and Yoder 1997). Two central elements of most programs are abatement support and compensation. Abatement support takes the form of agency consultation services, abatement activities performed by agency personnel at landowners' request, and subsidies for abatement capital such as fences and dispersal devices. Approximately 25 state and provincial agencies in the United States and Canada maintain compensation programs, which provide reimbursement for damage sustained by agricultural landowners (Wagner et al. 1997). Compensation is usually available for damage inflicted on specific property types, and by specific wildlife species. In return for compensation, agencies often place requirements on landowner abatement, land-use practices, and hunting access.

Compensation and abatement programs are also maintained by at least one private environmental group, as well as various public wildlife agencies worldwide. Defenders of Wildlife currently offers compensation to livestock producers near Yellowstone National Park who suffer depredation from reintroduced wolves, and for grizzly bear predation around Glacier National Park. From 1987 to February 2000, Defenders of Wildlife has compensated 113 ranchers a total of US$112,107 for 149 lost cattle, 319 lost sheep, and 14 other units of livestock (Defenders of Wildlife 2000).

Wagner et al. (1997) provide a summary of wildlife compensation programs. They also list 6 possible motivations for damage compensation programs: 1) to account for severe losses that may threaten the livelihood of agricultural producers, 2) to address common problems involving a large proportion of citizens, 3) to offset restrictions on abatement tools due to animal rights concerns, 4) to address wildlife problems made more severe by management actions taken by government agencies, 5) to address recently emerging or increasingly more severe wildlife damage problems, and 6) to address problems caused by highly valued species. The authors came to the conclusion that motives 4, 5, and 6 are likely explanations for the use of compensation programs, but provide no underlying conceptual model for understanding why compensation programs are appropriate.

This paper examines compensation and abatement programs as a means of contracting over wildlife management on private land. A model is developed that sheds light on the economic structure of compensation and abatement programs, and the motivation for maintaining these programs as a contracting tool. The model is based on 2 fundamental assumptions: 1) that wildlife damage law and policy is designed as if to maximize the net value of wildlife populations, and 2) that landowners are in a unique position of control for managing wildlife on their land, regardless of how the legal rights to utilize and/or regulate wildlife are distributed. The implications of the model are then examined in the context of compensation and abatement programs in the United States and Canada. The model is generally consistent with the findings and conclusions of Wagner et al. (1997) outlined in the previous paragraph, and thus provides a conceptual framework for understanding and addressing wildlife damage on private land and to private property in general.

THEORY

For modeling purposes, a clear distinction will be made between the beneficiaries of the wildlife stock and the owners of wildlife habitat. Assume 2 specialized producers: 1 farmer who produces crops and owns the land upon which the wildlife range, and a neighboring wildlife manager who values the wildlife for hunting and non-consumptive uses. This distinction allows a relatively simple comparison between economically efficient (net-value-maximizing) levels of hunting pressure by hunters and damage abatement by farmers and private incentives for hunting and damage abatement. This comparison between private and social optima then forms the foundation for an analysis of the factors that inhibit efficient hunting and abatement levels and shape wildlife damage policy.

Independent action and efficiency: a comparison

Consider first the objectives and choices of the farmer and the wildlife manager when acting independently. The farmer's objective is to minimize damage by utilizing an abatement input x:

$$V^f = \max_x(1 - \delta(x; h))y - cx, \quad (1)$$

where y is potential (before damage) revenue from farming, $\delta(\cdot) \in (0, 1)$ is the damage rate, and c is the marginal cost of abatement. Hunting effort h by the wildlife manager is taken as exogenous by the farmer when the 2 are acting independently. The damage decreases at a decreasing rate with respect to abatement in the economically relevant range of x: $\delta_x < 0$, $\delta_{xx} > 0$ (subscripts represent derivatives – e.g., $\delta_{xx} = \frac{\partial^2\delta}{\partial x^2}$). The first order condition for the farmer is

$$-y\delta_x - c = 0. \quad (2)$$

This condition implies that the farmer will set x so that the value of reductions in damage from an additional unit of x equal the unit cost of x.

The wildlife manager may benefit from wildlife in 2 ways: by valuing the flows from the wildlife stock in the form of hunting, and by valuing the wildlife stock itself. The benefits from hunting and wildlife for the wildlife manager will be modeled as

$$V^w = \max_h \alpha f(h) + \beta w(h; x) - rh, \quad (3)$$

where r is the marginal cost of hunting effort or provision of hunting services, and $\alpha f(h)$ are hunting benefits for a given wildlife stock with $\alpha > 0, f_h > 0$ and $f_{hh} < 0$. The value of the wildlife stock is $\beta w(h; x)$, with $\beta > 0$, $w_x < 0$, $w_h < 0$, and $w_{hh} > 0$. The value of the stock itself (βw) is its net present value for future production of hunting services as well as its present value for non-consumptive uses. This formulation allows recognition of the value of future use of the stock without explicitly introducing the complications of a dynamic analysis.

The wildlife manager harvests (hunts) to maximize this benefit function, subject to the farmer's abatement action. He does so by setting h to satisfy

$$\alpha f_h + \beta w_h - r = 0. \quad (4)$$

This condition implies that the wildlife manager hunts to the point that the marginal benefit from hunting equals the marginal cost of hunting in terms of reductions in the wildlife stock and the cost of providing hunting services.

Above, the farmer and the wildlife manager are assumed to make their choices independently of each other as described, but their choices affect each other: hunting affects the damage rate, and abatement affects the value of the wildlife stock. As a result, independent action will lead to inefficient allocation of these 2 inputs because the individuals do not bear the full costs and/or benefits of their own actions. For comparison, consider joint maximization of the net value of the wildlife stock:

$$V = \max_{h,x} \alpha f(h) + \beta w(h, x) - y\delta(x, h) - cx - rh, \quad (5)$$

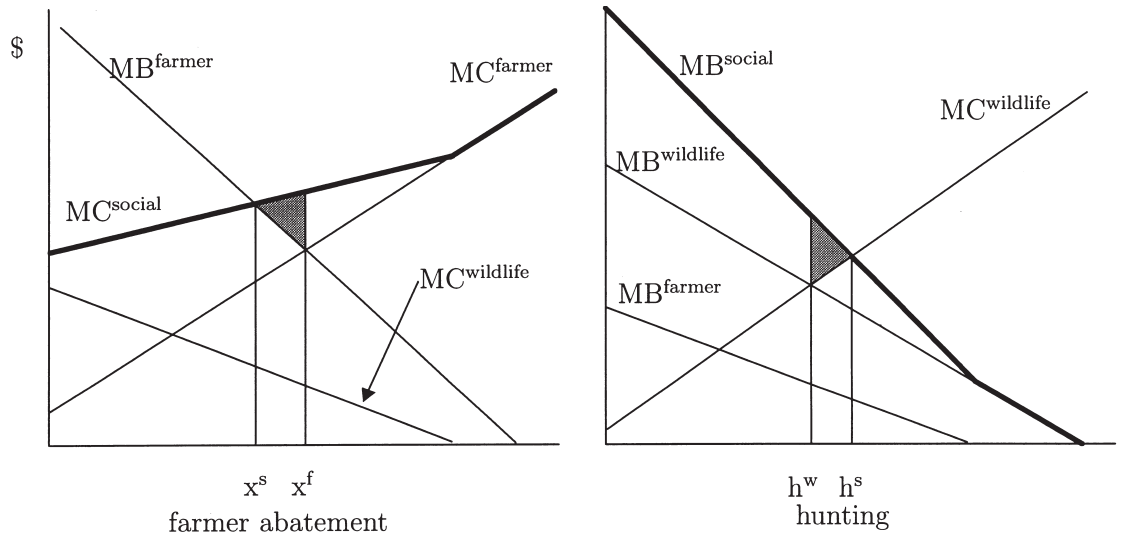

Fig. 1. A comparison of private and optimal abatement and hunting levels.

Hunting and abatement are assumed to be technical substitutes in abatement, so that $\delta_{bx} = \delta_{xb} > 0$. The first-order condition for the joint maximization problem is

$$\alpha f_b + \beta w_b - y\delta_b - r = 0 \quad (6a)$$

$$\beta w_x - y\delta_x - c = 0 \quad (6b)$$

Because hunting pressure and abatement effort are set to include their marginal effects on both the value of wildlife uses and the damage rate, all effects are internalized and this result is efficient.

Fig. 1 summarizes the independent and efficient results. In both panels, "MB" stands for "marginal benefit," the benefit accrued from a unit of the effort, and "MC" is "marginal cost," the cost of an additional unit of effort. In the left frame, MC^{farmer} is the marginal cost to the farmer of the farmer's abatement, and MC^{wildlife} is the loss of value in the wildlife population resulting from an additional unit of abatement, and MC^{social} is the vertical sum of the two marginal cost curves. Abatement level x^f represents the farmer's private optimal abatement level, defined by the intersection of MC^{farmer} and MB^{farmer} (as required by equation (2)). Abatement level x^s represents the social optimum, which accounts for the marginal damage to the wildlife population imposed by the farmer's abatement effort. The same logic underlies the right frame of Fig. 1.

The crucial result of the analysis thus far is that when individuals consider only their private benefits and costs (not those of others affected by their actions), too little hunting, and too much abatement will occur relative to social optimum. Thus, to maximize the net value of wildlife, hunting pressure should account for wildlife-inflicted damage, and damage abatement should account for any foregone gains from hunting or wildlife viewing. Assuming costless contracting, the gains from changing abatement and hunting rates to their respective efficient levels equals the sum of the 2 triangles that lie between the private and socially optimal effort levels in Fig. 1.

Given that the net value of the wildlife stock may be increased by altering abatement and hunting effort from private levels, the next question, which leads directly to policy implications, is how to instigate such a change. The following section examines this problem in the context of an environment where the participants – the landowner and the wildlife manager – have incomplete information about the other's actions, and monitoring private actions is difficult and costly. In this environment, the form of contract (law or policy) will be determined to a large extent by the nature of the information deficiencies and contracting costs associated with implementing a contract.

WILDLIFE DAMAGE POLICY: CONSTRAINTS AND ALTERNATIVES

The above analysis is based on the implicit assumption that the farmer effectively has the right to perform any type of abatement at any level, and the wildlife manager effectively has the right to set the hunting rate. No other property rights to wildlife are specified. In reality, state and federal governments in the United States hold legal jurisdiction over wildlife, and they enforce restrictions over actions that affect the value of the wildlife stock such as harassment, hunting, and trapping. This legal arrangement can be viewed as a contractual response to overharvesting that evolved through common law into specialized game agencies. (Lueck and Yoder 1997).

Legal jurisdiction, however, is not synonymous with complete control over a resource. In reality, information about private land use practices is not costlessly available to public wildlife managers. This means that enforcement and control of the use of wildlife resources on private land will be costly and incomplete. The value of a given form of contractual arrangement (policy or law) for managing wildlife depends in part on how costly it is to induce a given contracted change in resource allocation.

The model presented above will now be extended with the following additional maintained hypothesis: the farmers' abatement labor effort is likely to be among the most difficult activities to monitor by the wildlife manager. Trespass laws and specific knowledge about the landholding and surrounding area provide landowners with a substantial information advantage about the abatement effort and use of their own land. The potential for hidden abatement action (or inaction) makes contract enforcement difficult and costly for labor contracts in general, and is the basis for a vast literature on contract structure applied to a wide variety of problems. Empirical analyses include Leffler and Rucker (1991, timber contracts), Allen and Lueck (1992 1993, cropshare contracts) and Knoeber (1989, broiler chicken production).

Consider an illustration of this problem. Suppose that the wildlife manager agrees to pay the farmer up to the full value of the wildlife services lost due to a unit of abatement effort in exchange for a unit reduction in farmer abatement. In principle, the farmer would accept any payment equal to or greater than the marginal private benefit of abatement, because this is what the farmer is giving up by reducing abatement. The result would be an equilibrium of x^s and a total payment to the farmer up to the size of the gray triangle on the left-hand panel of Fig. 1. However, for the wildlife manager to be willing to pay the farmer, he must be

confident that the farmer will in fact reduce abatement by that much. To be sure of this, the wildlife manager must monitor the farmer's abatement effort. Honesty and integrity of the farmer notwithstanding, the farmer still has an economic incentive to perform the abatement he said he wouldn't perform if there is a chance of not being caught. Because monitoring landowner abatement labor such as this is particularly difficult and costly, there will usually be a substantial possibility of not being caught. This problem reduces the value of a payment contract based explicitly on farmer abatement labor effort. If monitoring farmer abatement is prohibitively costly, the contract would have little or no economic value.

What can be said about wildlife damage policy in light of this enforcement problem? Three types of contracts (laws and policy) over wildlife damage are common, and they will be examined in detail with the support of the model: 1) landowner exceptions to general regulations on harassing and killing wildlife,[1] 2) wildlife agency abatement support, and 3) compensation programs. These contracting instruments are not mutually exclusive. Each has its comparative advantages as incentive instruments, each of them has weaknesses, and all 3 or a combination of them are often utilized by an agency to address wildlife damage on private land.

Abatement rights and restrictions

The benefits and costs of regulatory restrictions are perhaps the most straightforward to understand. The social benefits of restricting abatement are, at best, the value of the gray triangle in Fig. 1. It can be shown with the mathematical model and the figure that this triangle increases with increases in the marginal value of the wildlife affected by the abatement and the marginal impact of abatement on the value of the wildlife. Therefore, despite the costs of enforcement, as these factors increase, the value of enforcing abatement restrictions increases.

A special case to consider is that in which the potential costs of abatement restrictions tend to be so high that they outweigh the total social costs of allowing abatement. To see this, suppose that the problem animal was a bear, and the only effective abatement method was a rifle. Then consider 2 possible types of damage the bear might inflict: personal injury or death, or damage to a garbage can. To kill a bear in defense of health or life can be represented by a high marginal benefit, whereas defense of a garbage can will provide less benefit. Relaxing restrictions on shooting a bear for personal defense is more likely to be economically justifiable than shooting in defense of a garbage can. Thus, as the potential costs of abatement restrictions increase, such restrictions become less economically justifiable.

Specific implications can be drawn from the general analysis above. These and subsequent implications will be phrased in normative terms based on the assumption that the objective of wildlife management is to maximize the net value of wildlife. These normative statements can be interpreted in 2 ways: First, if wildlife management policy has in fact developed as if to maximize the net value of wildlife resources, then existing wildlife policy should be generally consistent with these implications. Second, if an explicit objective of wildlife management is to maximize the net value of wildlife resources, then the design of wildlife damage policy should reflect these implications. Each of these implications apply *in ceteris paribus* terms; holding all else constant. Some of these implications may seem self-evident, but this is probably because they are in fact reflected in current wildlife damage policy. They are included to illustrate the empirical promise of this general model.

> Implication 1. Abatement restrictions should apply to highly valued wildlife species.
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> Implication 2. Abatement restrictions should apply for abatement methods that are relatively harmful to the wildlife population.
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> Implication 3. Abatement restrictions should be weak if the value of the resulting increase in damage is high.
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> Implication 4. Supplementary hunting should be promoted if it is productive in terms of damage reduction.

Factors that increase the costs of enforcement will, as discussed above, reduce the extent that direct abatement restrictions are imposed, or at least the extent to which they are effective. Thus the same restrictions imposed on landowners (such as restrictions on killing game out of season), may be harder to enforce for landowners than nonlandowners. Furthermore, Lueck and Yoder (1997) argue that large landowners are likely to internalize more of the effects of their abatement and wildlife management activities, so their private wildlife use will tend to be closer to efficient, and abatement restrictions should tend to be less restrictive.

Compensation

Compensation for damage from a wildlife manager to a landowner is essentially a form of damage sharing. Compensating a landowner for damage reduces the marginal benefit to the landowner of abatement effort. To see this, consider the case in which the wildlife agency compensates the landowner for 100% of the

[1] The landowner exceptions are in addition to more generally applicable rights to defend property, such as additional hunting rights not accorded to nonlandowners.

damage sustained by wildlife, as well as any costs the landowner accrues as a result of the transaction. The landowner will have no incentive to expend abatement effort, because he or she gains nothing from it.

The benefits of compensation, then, result from the fact that farmers have a weaker incentive to pursue abatement that is potentially harmful to the wildlife population. If there were only 1 implementable form of abatement for the landowner to use, the efficient level of abatement could be induced by setting the compensation rates such that the effective (post-compensation) marginal product of private abatement equals the marginal cost of private abatement. In the left panel of Fig. 1, as the compensation rate increases, the MB^{farmer} shifts downward. The efficient compensation rate would be that which shifted the MB^{farmer} curve downward until it crosses MC^{farmer} at x^s.

There is a crucial problem with compensation, however. If the landowner utilizes 2 or more abatement methods that differ in their impact on the wildlife stock, the incentive effect of compensation is a double-edged sword. Suppose the landowner privately utilizes 2 abatement methods: 1 that harms the wildlife, and 1 that has no effect on the value of the wildlife. Providing compensation, suppose again 100% compensation, will remove the landowner's incentive to perform both kinds of abatement. For a given level of savings in terms of the value of the wildlife stock, the total damage sustained will be higher because the landowner will reduce the farmer's use of both types of abatement, and compensation as a contracting mechanism will be more costly. Loosely speaking, the efficiency gains from a compensation program are lower if the farmer's abatement options have highly variable effects on the wildlife stock. This is because the compensation mechanism does not target abatement effort directly, but only indirectly through its effect on total damage.

Contracting costs are associated with the maintenance of a compensation program as well. Compensation is contingent on the level of damage, and requires explicit and credible measurement of total damage. The process of measuring and verifying the cause of damage is not costless, and the aggregate value of a compensation program will be reduced by the cost of measuring damage.[2] Measurement costs depend on various factors stemming from both the technical process of damage measurement, and bargaining and monitoring issues between the 2 parties stemming from virtual inevitability of imperfect measurement of damage. One particularly important determinant of measurement costs is heterogeneity of the damaged resource. As heterogeneity of the damaged resource increases, the costs of calculating damage are likely to increase. Along the same lines, damage to annual crops is likely to be easier to calculate (more accurately calculated) than change to perennials, because the impact of current damage on future value of a perennial crop (e.g., the value of damage to pine seedlings) will be more difficult to ascertain.[3] Furthermore, existing markets for an agricultural resource provide information about resource value in the form of prices. If a market for a damaged commodity does not exist, this increases the difficulty of measuring the value of damaged property. Implications of the foregoing discussion include:

Implication 5. Compensation programs should target valuable species.

Implication 6. Compensation programs should target individuals who maintain significant control over the wildlife stock and/or its habitat.

Implication 7. Compensation programs should target homogeneous and annual crops, or other property for which damage is relatively easily quantifiable.

Implication 8. Compensation programs should target products for which substantial markets exist.

Abatement support and subsidies

Consider again the 2 forms of abatement discussed in the previous section on Compensation: 1 form that harms the wildlife stock, and 1 form that does not. It would appear that the wildlife manager should be indifferent to the benign form of abatement, and support reductions in abatement that harms wildlife. At first glance there is no apparent reason for wildlife managers to promote any form of abatement. Yet most wildlife agencies provide abatement support of various kinds, including consultation services, direct support in the form of agency personnel labor, and subsidies for various forms of abatement technologies such as fencing.

A plausible economic basis for agency abatement support is that different forms of abatement act as technical substitutes for each other. That is, the use of 1 form of abatement reduces the marginal productivity and leads to a decline in the marginal productivity of other forms of abatement when simultaneously applied. For example, the installation of a fence for keeping deer out of a crop field will reduce the damage-reduction benefits that accrue from thinning the local deer population in the general attempt to reduce damage. Thus, increased use of a benign abatement technology like fencing will reduce the incentive that farmers have to reduce the local deer population or rely on depredation permits in an attempt to reduce crop damage.

[2] These costs are analogous to the "pricing" or "metering" costs as discussed in McManus (1975) and Alchian and Demsetz (1972), respectively.

[3] Other factors affecting measurement costs may include spatial diversity and patchiness of crop types.

Two characteristics of fencing make it an excellent example of an abatement input that might serve as a basis for contracting between a farmer and a wildlife manager. First, its maintenance is relatively easy to monitor by both parties. Unlike the farmer's labor effort, its continued existence and maintenance is observable at any given time. Second, it has a relatively low impact on the wildlife population. As discussed above, the installation and maintenance of a fence will reduce the incentive that farmers may have to perform abatement more harmful to the wildlife stock. If fencing is a productive abatement tool, it may therefore be in the best interest of a wildlife manager to subsidize the installation of fencing and monitor its continued maintenance by the farmer as part of a contract in order to reduce the farmer's incentive to perform more harmful abatement methods.

Wildlife manager abatement labor on private land is another interesting substitute for farmer abatement labor effort. There are 2 differences between these 2 forms of abatement. The wildlife manager has a stake in wildlife (if only as an intermediary for hunters and other stakeholders), and it is likely to be easier (less costly) for a farmer to monitor the wildlife manager's activities on the farmer's own land than it would be for the wildlife manager to monitor the landowners activities on the farmer's own land.[4] Thus, we can assume that the wildlife manager will attempt to minimize the impact on the wildlife stock as he or she carries out contracted abatement activities under the watchful eye of the farmer.

It is important to recognize that while different abatement inputs may be substitutes for each other, they are generally not perfect substitutes. For example, landowners are likely able to more effectively address damage problems in which timing of abatement is crucial and living on site helps in this process. Fencing may not be a very productive abatement input or may be prohibitively costly, despite its useful characteristics discussed previously. Implications from this discussion include the following:

> Implication 9. Abatement programs should promote agency personnel abatement labor.
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> Implication 10. Abatement programs should promote benign abatement techniques.
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> Implication 11. Abatement programs should promote monitorable fixed abatement capital.

Joint compensation and abatement programs

Recall that damage compensation reduces the incentives for landowners to carry out all forms of abatement including benign abatement. Thus, compensation becomes a costly way of reducing the overall impact of private abatement on the value of the wildlife stock. It follows that if a wildlife manager maintains a compensation program, the benefits associated with the support of benign and monitorable abatement technologies are twofold. First, the use of these inputs further reduces the incentive of farmers to pursue more harmful abatement methods due to the substitution effect. Second, it directly offsets the compensation's negative impact on the farmer's private incentive to use benign methods. Benign, monitorable abatement techniques therefore become especially valuable in conjunction with a compensation program. An additional implication is:

> Implication 12. Compensation should be contingent on the use of monitorable, benign abatement techniques.

DISCUSSION

The implications of the model outlined in the above sections will be discussed in the context of the Wisconsin Wildlife Damage and Abatement and Claims Program and a broad set of state wildlife regulations to show that wildlife damage laws and policy are generally consistent with a wealth maximization framework.

Wisconsin Wildlife Damage and Abatement Program

The Wisconsin Bureau of Wildlife Management (BWM) Wildlife Damage Abatement and Claims Program (WDACP) incorporates 3 approaches to addressing wildlife damage. It provides up to 75% cost-share abatement support for farmers through participating county agencies, it provides for a depredation permit ("hot spot" permit) system that allows landowners with special permits to shoot problem deer, and it provides compensation up to US$15,000 per farmer per year. Farmers sustaining damage by deer, geese, bear, and turkey are eligible, and 80 to 90% of estimated damage is due to deer. Surcharges on Wisconsin bonus deer permit fees earmarked for expenditure on damage claims and abatement generated almost US$3.5 million in 1996, with almost US$1 million put toward abatement and US$1.7 million toward compensation. For the 1995 fiscal year, 11.4% of the total departmental budget went to the wildlife damage program. Wisconsin's BWM damage estimates in 1996 averaged US$2,813 per claimant (farm), and 1,266 claimants received on average US$2,324 in compensation.

The BWM issued 394 hot spot permits to landowners in 1995, under which 3,908 deer were killed (as compared to general bow and gun permit kills of 467,271). Most crop damage occurs before hunting season, which generally is held in late October, and hot

[4] Note that gains from specialization do not necessarily differentiate farmer abatement from wildlife manager abatement. "Farmer abatement labor" may well be carried out by private abatement specialists, or maybe even by the personnel of public agencies not mandated to manage the wildlife population. The important difference is that wildlife manager or their constituents are the beneficiaries of benign abatement techniques.

spot permits allow farmers (or hunters at the farmers request) to shoot deer out of season on land suffering crop damage. Issuance of the permit is contingent on reasonable prior abatement by landowners and evidence of at least US$1,000 of deer damage to crops. The land must be open to hunting for the following hunting season, and the landowner must also sign a contract agreeing not to deny a hunter's request for access to his land unless 2 hunters per 40 acres are already on his land at the time of the access request. That the BWM issues permits implies that landowners may not kill these game species at their own discretion or without prior permission. Thus, damage abatement of this form, which results in the loss of the value of an individual game animal as a hunting target, is restricted (Implications 1 and 2).

Although the permits issued to a farmer in a given year may all be used by the farmer, the farmer may keep only 1 of the deer taken with his or her allotment. Most hot spot permits are made available to hunters (Horton and Craven 1997). Thus, the value of the deer as game is captured by allowing hunters to perform the abatement (implication 4). The overall benefits of killing a deer out of season may be lower than the benefits accrued from hunting during the regular season due to time, location, and hunting's effect on the deer population dynamics. Thus, the tradeoff is between the costs of allowing hunters to harvest out of season and the gains from both reduction in damage and reduction in incentives for landowners to pursue alternative abatement efforts that may harm the wildlife population while not capturing any of their benefits.

When BWM representatives (usually county extension agents) assess claims, they usually recommend the use of abatement techniques. These abatement recommendations become requirements for receiving compensation, and form the basis of the abatement costs that are shared by the landowner and the agency. In addition to hot spot permits, commonly implemented abatement methods include the installation of various types of fencing, the use of lure crops and scaring devices, and the application of chemical deterrents.

Hot spot permits as a means of marrying hunting benefits with damage reduction have already been discussed. Fencing is a relatively benign form of abatement and is easily monitored (Implications 10 and 11). The BWM has 15-year written contracts for installation and maintenance of permanent fences for deer damage abatement, and fences are installed around approximately 13% of fields for which the BWM provides compensation. As implied by the model, the agency may benefit from subsidizing fencing in 2 ways, even if the fence has no discernible (or even negative) impact on the wildlife population. First, the installation of a fence will reduce landowner incentives to perform other abatement activities that may be more harmful to the wildlife stock. For example, a fence that keeps deer out of crop fields will reduce the incentive for farmers to shoot deer on sight or clear scrub from around the field that may act as valuable (yet inexpensive) forage and cover for deer. To put it another way, subsidizing a fence to reduce damage provides positive incentives to landowners to leave or even promote wildlife habitat on their land. Second, when used in conjunction with a compensation program, the subsidy will counteract the reduction in the incentive to perform abatement that the compensation mechanism induces (Implication 12).

Damage eligible for compensation under the Wisconsin WDACP includes damage by deer, bears, geese, or turkeys. The type of damaged agricultural property eligible includes commercial seedlings or crops growing on agricultural land, harvested crops remaining on agricultural land, orchard trees, nursery stock, apiaries, or livestock (Wisconsin Code §29.889 (6), 1997-1998). Thus, compensation is provided only to those property owners who have control over the resources (land) utilized by the valuable game species wildlife (Implication 6) for damage imposed by valuable game species (Implication 5).

Not only does the BWM provide out-of-season hot spot permits, but the farmer is required to allow hunting on compensation-eligible land during the open season. In 1 of 2 access rules a farmer can choose (called the "managed hunting access" plan), the farmer must allow up to 2 hunters per 40 acres of eligible land to hunt at any given time during the open season.[5] This provision serves a purpose similar to that of hot spot permits by promoting abatement by hunters and offsetting the disincentive for abatement generated by compensation (Implications 4 and 5). The right of landowners to control hunter access to their land becomes a critical issue for herd management in regions where private agricultural land is a major source of wildlife habitat (Witmer and DeCalesta 1992, Vander Zouwen and Warnke 1994, Gardner 1997, McCabe and McCabe 1997, McShea et al. 1997a). As with abatement in general, compensation reduces a landowner's incentive to allow hunting on his or her land because it reduces the cost of wildlife to the landowner. This contract stipulation allows agencies to utilize a compensation program to overcome this problem and address access issues as well. Furthermore, monitoring this requirement is relatively easy. Landowners are included in a list of participants that is available to hunters, and are required to keep a log of hunters on their land. Hunters have the right and an incentive to report to the agency if they feel they have been disallowed access.

[5] A hunter may be turned down if he or she is intoxicated, causes property damage, or if the hunter does not secure prior permission from the landowner (Wisconsin code §29.889 (7M) 1997-1998). These exceptions are consistent with the model as well.

Table 1: State damage policies[a]

ST	No permit required		Out-of-season depredation permits		
	species	to defend	issued for	to defend	carcass owner
AL	CY	any	game	crops	
AK	pred	any	pred, BV	any	
AZ	pred	lvstck	game	crops	D
CA			DR,EK,BV	any	LL
CO	BR,ML	lvstck	any	any	D
CT			any	any	LL
FL			DR,BR	crops	
GA			BR	bhive	
ID	BR,ML,WF	lvstck	any	any	D
IL			pred,furb	any	D
IN			any	any	
IA	FH		any		LL
LA	BV	any	any	any	
ME	any	lvstck,crp	BR	bhive	D
MD	various	any			
MA	any	not grass			
MI			DR,TE		
MN			various	any	D
MO	most	any	DR,TK,BR		
MT	pred	lvstck	BV	any	D
NE	pred	lvstck			
NV			furb	any	D
NH	any	any			
NM	any	lvstck	BV,TE,game		
NY			various	crops,lvstck	D
ND	pred,furb	any	BR,ML	any	LL
OH			any	any	D
PA			DR	any	LL
RI	furb	any	deer	crops	D
SC	BC	any	any	any	D
SD			any	any	
TX			any	any	LL
UT			BV		
VT	DR,BR	crops			LL
VA	FX	lvstck	various	any	L
WA	any	any			
WV			DR,BR		
WI			DR,BR,WF		
WY	pred	lvstck			LL

SPECIES: AN=antelope, BC=bobcat, BR=bear, BV=beaver, CY=coyote, DR=deer, EK=elk, FH=hatchery fish, FX=fox, GB=game birds, ML=mountain lion, MS=moose, NN=non-native species, PH=pheasant, TE=threatened or endangered, TK=turkey, WF=wolf, game=unspecified game, bgame=big game, pred=unspecified predators, various=large specific list of various game and/or predators. **RESOURCE DAMAGED:** any=unspecified property or wildlife, lvstck=livestock, bhive=beehive. **OWNERSHIP:** D=Department, L=landowner, LL=landowner, limited use. **ABATEMENT SUPPORT:** C=consulting, L=abatement labor, K=abatement capital.

[a] Data for these tables were taken from state fish and game regulations, Musgrave and Stein (1993) and Wildlife Management Institute (1997).

Table 2: State damage policies[a]

ST	abatement support	Compensation for (species)	Contingent on abate-ment	Contingent on non-posting	Contingent on access fees
AK	C,L,K				
AZ	C,L	BV			
CO	C,L	BR,ML,DR,EK,AN	x	x	x
ID	C,L	DR,BR,EK,MS,AN,ML	x	x	
IL	C,L				
IN	C,L				
KS	C,K				
KY	C,L,K	CY			
ME	C,L,K				
MD		BR			
MA		DR,MS			
MN		WF,EK			
MO	C,L,K				
MT	C,L	bgame			
NE	C,L				
NV	C,L,K	DR,EK,AN			
NH	C,L,K	game,ML,BR	x	x	
NM	C,L,K				
ND	C,L,K				
OH		CY			
PA	C,L,K	BR,CY	x		
SD	C,L,K				
TX	C				
UT		DR,EK,BR,ML,PH,AN,MS,BV			
VT	C,L,K	BR,DR	x		
VA		BR,DR			
WA		DR,EK	x		
WV		BR			
WI	C,L,K	DR,BR,WF	x	x	x
WY		bgame,WF			

SPECIES: AN=antelope, BC=bobcat, BR=bear, BV=beaver, CY=coyote, DR=deer, EK=elk, FH=hatchery fish, FX=fox, GB=game birds, ML=mountain lion, MS=moose, NN=non-native species, PH=pheasant, TE=threatened or endangered, TK=turkey, WF=wolf, game=unspecified game, bgame=big game, pred=unspecified predators, various=large specific list of various game and/or predators. **ABATEMENT SUPPORT:** C=consulting, L=abatement labor, K=abatement capital.

[a] Data for these tables were taken from state fish and game regulations, Musgrave and Stein (1993) and Wildlife Management Institute (1997).

State law and regulatory policy

Tables 1 and 2 provide an overview of some of the wildlife damage and management policies for the 50 states. Blank spaces indicate that either state statutes or written agency policy did not apply to column description for that state, or there was no mention of the column topic in any of the sources. The data in these tables were spot checked with various agency personnel during the course of this research.

Table 1 shows the rights of landowners to take (kill) protected species, where protected species are those species for which the wildlife manager (wildlife agencies) impose a closed season for part the year. The second and third columns of Table 1 entitled, *"no permit required for protected species lists protected species"* that landowners may destroy without prior agency permission (Musgrave and Stein (1993) and state statutes). In general, species that have the potential to inflict significant damage in a short amount of time are widely represented; livestock predators, for example. In this case, the marginal value of a rapid response to depredation is high and restrictions on rapid response are costly (Implication 2).

Note that valuable big game species such as deer and elk are absent from the second and third columns of Table 1 (with the exception of Vermont). The high marginal value for hunting of a big game species results in large potential loss of value when a big game animal is taken for depredation purposes by non-hunters (Implication 8).[6] Instead, the regulatory response has been to allow abatement, but only in a more restricted form that both provides discretion on the part of the agency and in some cases facilitates the transference of "abatement rights" to hunters (columns 3-5 of Table 1, *out-of-season depredation permits.* Sources: Musgrave and Stein (1993) and state statutes). This way (as discussed in the context of Wisconsin), the value of the game species as a target for hunters is not entirely lost in the process of abatement.

Some wildlife departments also organize special out-of-season depredation hunts in order to address specific damage problems by game animals such as deer. This too acts to address property damage problems while capturing some of the benefit of the game animal through sport hunting (Implication 11).

Note also that when landowners retain ownership of the carcass, there are usually legal limits on its use (Table 1, column 6). For example, a deer shot with a depredation permit by law might only be used by the landowners immediate family. This can be viewed as a means to limit the potential value of a game carcass in order to reduce incentive for fraudulent requests for depredation permits.

Table 2 focuses on agency abatement and compensation programs. Most state wildlife agencies are explicitly authorized by state statute to provide abatement support in the form of consulting, abatement labor, and/or abatement capital. State wildlife agencies are the regulatory authority over wildlife, but most wildlife agencies cooperate with the United States Department of Agriculture, Wildlife Services Program (WS). In many cases, WS performs much of the damage control work. In some cases, particularly with big game species, WS activity is monitored by state wildlife agencies (Fagerstone and Clay 1997). In other cases, such as with coyote control in many western states, wildlife agencies participate little or not at all. In this context, WS acts as a representative of agricultural interests, and may be a mechanism to internalize the joint interests of landowners in dealing with damage. At current population levels in the west, the relatively low marginal value of an individual coyote in terms of trapping value, hunting value, and coyote population health provides relatively little incentive to limit lethal abatement techniques (Implication 1).[7]

Up to 80% of agencies that provide compensation for damage also provided abatement assistance, and 70% of them tie compensation payments to some form of abatement requirements (Wagner et al. 1997).[8] In some states, compensation is also contingent on allowing hunter access to their land, which reduces the local population while providing hunting benefits to the public. When access fees are charged by landowners, compensation payments are often reduced by the revenues received from charging for access (Wisconsin is one state that does this).

Compensation programs tend to be reserved for relatively valuable species (last 2 columns of Table 2, and Wagner et al. (1997)). As in Wisconsin, certain requirements are usually placed on landowners, such as having to follow abatement recommendations of the wildlife agency and, for game animals, allowing hunters on the land on which damage is occurring. Hypotheses regarding abatement and compensation programs discussed in the previous section in the context of Wisconsin are broadly supported across states.

As Table 1 shows, Kentucky, Ohio, and Pennsylvania have compensation programs for livestock depredation by coyote through their departments of agriculture, but in all cases the programs are based on domestic dog laws and are paid for out of general county or state funds rather than by producers. Compensation programs have been discussed at length among sheep producers, but apparently no such program has ever been implemented that is entirely funded by sheep producers (Wagner 1972, p. 46-48).

If the costs of measuring damage are high, the value of a compensation program as a contracting tool will be low. The model therefore suggests that compensation programs will be more likely when damage measurement costs are low. Many programs specify the types of damage that are eligible for compensation (Wagner et al. 1997). For example, most or all programs for damage by ungulates pay for damage to seasonal crops, for which damage to a given crop is relatively easy to calculate. Compensation for damage done by predators is often limited to livestock losses, and bear damage compensation payments are in some cases limited to beehive damage. No programs compensate for bodily injury, and none compensate for forest products or damage to standing timber or seedlings. Actual damage to both of these types of property is likely to

[6] When laws specify which type of agricultural resource can be legally defended by non-permit taking, it tends to be livestock and field crops.

[7] The growth of the animal rights movement represents an increase in the perceived costs of various lethal abatement methods. The model provides implications about the impact of such a change in perceptions, but they will not be addressed here.

[8] The data in Table 2 indicate lower percentages than those presented in Wagner et al. (1997). The data in this Table are based primarily on state statute requirements, whereas the Wagner et al. (1997) are based on survey results.

be difficult to accurately measure and is therefore less likely to be applicable for a compensation program (Implications 8 and 12).

CONCLUSION

This paper examines the structure of compensation and abatement programs for addressing wildlife damage to agricultural property. In doing so, it provides insight into the incentives of both parties for developing such contracts, and how participants' incentives are altered in the context of such contracts. It also examines the costs associated with maintaining such contracts, including measurement costs associated with damage assessment for compensation purposes, and the costs of monitoring contracted abatement labor.

The hypothesis that persistent institutions act as if to maximize wealth of public or common property resources subject to informational constraints and contracting costs has been argued widely (Alchian 1950, Stigler 1992), and in the context of wildlife law and regulatory structure more specifically (Lueck 1991, Lueck and Yoder 1997). This analysis provides a model and broad evidence to suggest that wildlife damage institutions are generally consistent with a theory of constrained wealth maximization over wildlife resources.

To the extent that maximization of the net value of wildlife resources for all interested parties is an explicit objective of wildlife managers, it provides a conceptual framework for designing wildlife damage and compensation programs to satisfy this objective. The model suggests that damage abatement and hunting policy should be designed in an attempt to consider the resource costs of wildlife populations and the benefits of wildlife populations, as well as the relative costs and effectiveness of implementing alternative policy structures.

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