Economics of Predator Control to Protect Agriculture: The Unanswered Questions

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Introduction

For centuries humans have attempted to control populations of mammalian predators to protect livestock populations. The United States government officially entered the predator control arena in 1915, when Congress appropriated funds for the control of wolves and coyotes (GAO, 2001). Federal and state agencies have since invested significant public resources to control predators to protect and to compensate agricultural producers for incurred losses. In 2007, for example, USDA APHIS Wildlife Services invested over $39 million in predation programs (USDA, 2008). Concurrently, growth in the environmental movement has raised concerns about the efficacy and morality of such resource use (Connolly, 2001, Hewitt, 2001). Recent controversy surrounding the removal of endangered species status for the gray wolf (*Canis lupus*), specifically the negative public opinion of state management plans that would manage wolves similarly to coyotes, is a case in point.

Although disagreements about predator control are unlikely to ever disappear, it may be time to cast the predator control debate in a new light. Recently there has been a growing recognition of the value of ecosystem services provided by private agricultural land. This is particularly true for wildlife habitat in the Rocky Mountain region (RM), where, despite large tracts of public land, wildlife depend on private lands for much of their habitat needs (Coupal, et al., 2004). Concurrently, rural and ex-urban development is placing increasing pressure on land historically shared between livestock and wildlife. As a result, profitable agricultural production may be the last line of defense protecting many valued ecosystems from being permanently altered by development.

Publicly subsidized predator control and compensation programs may be viewed as another tool to protect the provision of ecosystem services from private land. It is therefore increasingly important that policy makers have accurate scientific information about the effectiveness of such programs for protecting the profitability of agriculture. This information will help policy makers accurately assess the tradeoffs between agricultural sustainability and other social values (e.g. non-market values of predator populations). The purpose of this article is to review existing research in the light of this new context and to provide direction to target future research.

Financial Impacts of Livestock Depredation in the West

Predation continues to have a measurable financial impact on many sectors of the agricultural economy. This is particularly true for the production of sheep and lambs, where the value of losses due to predators, primarily coyotes, exceeded $6 million in 1994, 1999 and 2004 (Figure 1). These losses account for 2 – 11% of the annual total value of sheep production in these western states. Furthermore, predation routinely accounts for greater than 50% of the annual

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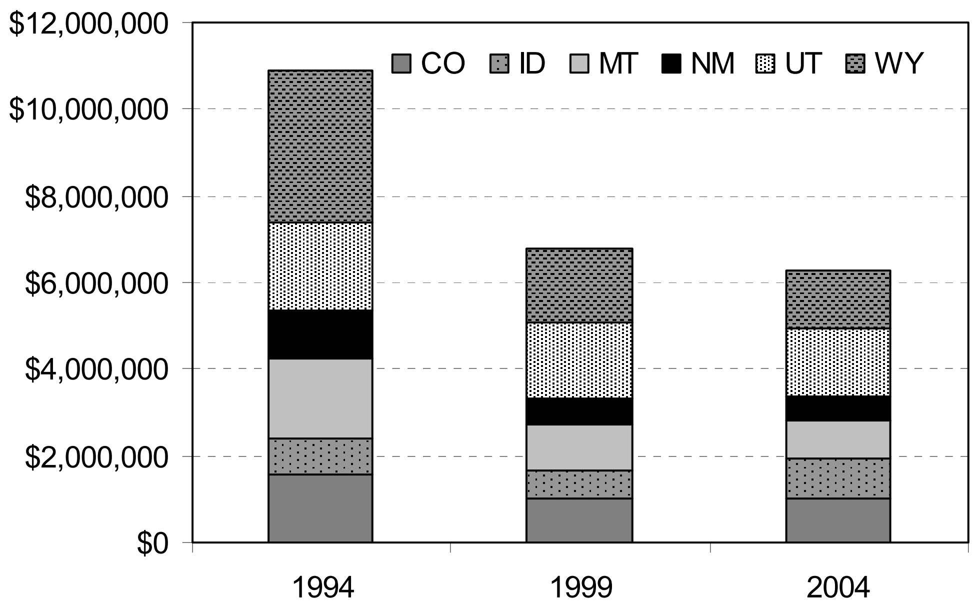
death loss of lambs in the RM region (National Agricultural Statistics Service, 1995, 2005, 2000).

Direct financial impacts of predation, however, are not limited to sheep and lambs. Predation losses generally account for 1-2% of total cattle inventory in the region and greater than 5% of total calf inventory (USDA, 2000). Additionally, in areas with robust populations of large predators (wolf and grizzly bear) predation on cattle and calves can be significant. The Upper Green River Cattle Allotment, located in the Greater Yellowstone Region of northwest Wyoming, confirmed predation by grizzly bears and wolves accounted for more than 50% of total death loss from 1995 to 2004 (Sommers, et al., 2008). An alternative study in the same region found that grizzly bears were responsible for 39% and 12% of total calf and adult cattle mortality, respectively (Anderson, et al., 2002).

Figure 1. Dollar value of sheep and lambs lost to predators by State, 1994, 1999 and 2004 [Source: National Agricultural Statistics Service (1995, 2005, 2000)]



Dollar figures are adjusted to real terms using the GDP deflator, base year 2004.

While the financial impacts of predation on livestock production are measurable, they remain small relative to the total value of production. As a result some have argued that federally subsidized predator control programs are unnecessary (e.g. Berger, 2006). Livestock operations in the west, however, routinely maintain slim to negative profit margins (Jones, 2004). Furthermore, the negative financial impacts of predation are not evenly distributed across the landscape. Thus, while the livestock industry in a given region may experience relatively small aggregate losses, those losses may primarily impact a few producers that operate in areas most prone to predation. If areas prone to high predation rates also coincide with agricultural land that is highly susceptible to land conversion (e.g. agricultural land into subdivision around the Greater Yellowstone Region), the financial impacts of predation may be an important factor threatening agricultural profitability. Thus, even small depredation losses that reduce annual gross margins can threaten the economic sustainability of agricultural production and the associated ecosystem service provided from agricultural lands.

Lastly, in addition to the direct effects of predation, the financial impacts of predation also ripple through the broader regional economy due to employment and income linkages across economic sectors. Jones (2004), for example, estimated that predation in the RM region in 1999 caused approximately $7 million in direct losses to the livestock industry. These direct losses led to an additional $5.6 million dollars of indirect losses in allied sectors.

Economics of Predator Control to Protect Agricultural Lands: State of the Literature

Economic theory suggests that the conversion of agricultural land to development will occur if the present value of the stream of net returns from agriculture is less than the net returns from development (Irwin, et al., 2003). Thus, policy-makers must understand how predator control programs contribute to the long term net returns of agricultural production to assess the effect of these programs on land protection. This implies the need to understand the following: 1) the biological relationship between relevant predators and their prey, including livestock; 2) how predator control efforts affect predator-prey relationships and thus the effect of predator control on livestock production; 3) cost-effectiveness of alternative control methods; and 4) the economic efficiency of predator control relative to alternative agricultural support programs.

The literature contains numerous economic analyses related to predator control efforts. Surprisingly few, however, directly model the biological predator-prey relationships such that the effects of explicit control efforts on livestock production can be derived. Several studies have explicitly modeled predator-prey relationships with respect to wildlife species of concern (Rashford and Adams, 2007; Shwiff, et al., 2005; and Skonhoft, 2006). These studies use available data to parameterize or statistically estimate functional relationships between either predator and prey populations, or alternatively, predator populations and levels of predator control effort. Thus they develop functional representations of the biological predator-prey relationships, which can then be explicitly integrated into an economic optimization problem.

Few studies have developed similar predator-prey relationships for livestock depredation. Data on the interactions between predators and livestock and livestock losses relative to specific control efforts have been collected in biological experiments (e.g. Anderson, et al., 2002, Wagner and Conover, 1999). Alternatively, regression techniques have been used to examine correlations between predator populations or control efforts and livestock outputs (Berger, 2006, Conner, et al., 1998). These studies, however, do not attempt to develop functional relationships. Moreover, studies of this nature tend toward the following (often by necessity): 1) focus on a single pair of predator and prey species; 2) have limited temporal and spatial extent; and 3) focus on one of a large suite of predator control alternatives applied at a single (or a few) level(s) of intensity. These studies do not reveal the range of substitution possibilities among the set of controllable (e.g. predator control efforts) and uncontrollable (e.g. weather and alternative prey populations) inputs, and the associated response of livestock populations (see Matulich and Adams, 1987, for an in-depth discussion of this problem). An exception to this criticism can be found in the bio-economic analysis of feral pig predation on lambs in Australia by Choquenot and Hone (2000). This analysis uses dynamic models of predator populations and lamb predation to simulate the economic impacts of multiple control options in a bio-economic model that incorporates exogenous factors (e.g. rainfall) and inter-specific competition.

The general lack of explicit models of predator-prey relationships in the context of livestock production has forced studies of the economic efficiency of predator control to use aggregate data approaches. Several studies, for example, have used a benefit-cost approach to examine the efficiency of programmatic expenditures on predator control (Bodenchuck, et al., 2000, Collinge and Maycock, 1997, Shwiff and Merrell, 2004, Shwiff, et al., 2006). These papers account, as accurately as possible, for aggregate benefits and costs, including indirect benefits (e.g. spillovers to other economic sectors) and indirect costs (e.g. non-programmatic costs born by individual producers). However, there is no direct relationship between alternative control efforts and agricultural profitability due to the aggregate nature of the data. The benefits of predator control, for example, are often measured by damages avoided assuming a linear relationship between control efforts and predation rates (e.g. predation rates are 1-3% higher in the absence of control efforts).

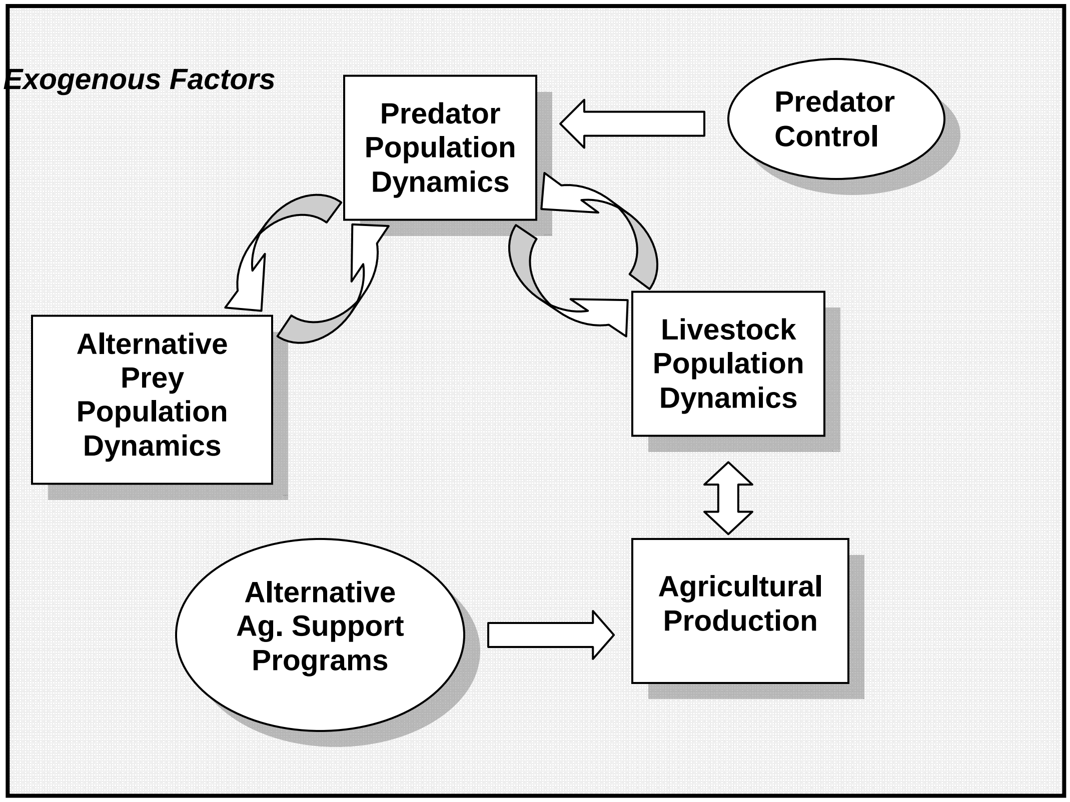
The aggregate benefit-cost approach is most useful for determining the aggregate net benefits of control expenditures and therefore justifying the existence of control program in general. This approach does not illicit the biological or economic tradeoffs between alternative control strategies and therefore cannot determine the cost-effectiveness of alternative control methods. It would be difficult to use this approach to compare predator control programs to alternative agricultural support programs as a means of preserving agricultural land because the aggregate benefit-cost approach does not directly link predator control to agricultural profitability.

Looking to the Future

Researchers and policy-makers appear to lack a firm understanding of the complex relationship between predator control programs and firm-level agricultural profitability. As a result, their currently exists no framework for analyzing the role that predator control programs can play in the broader effort to preserve agricultural land. Such a framework must explicitly model the population dynamics of predators and prey and these dynamics must be explicitly linked to agricultural production and policy decisions. The effects of predator control and alternative agricultural support programs can then be analyzed on the basis of how they impact agricultural profitability.

A general framework for integrating biological predator-prey models, agricultural production models and decision making is presented in Figure 2. The critical sub-systems are depicted with rectangles, while ovals represent inputs. These components are all incorporated within the larger rectangle indicating that each sub-system is a component of a larger integrated system. The integrated system includes exogenous factors, such as climate and public perception, that can influence each subsystem directly and the relationships between sub-systems. Climate, for example, will directly influence the population dynamics of individual species, which in turn will influence the relationships between related species. When threatened or endangered species are part of the system the exogenous factors, such as statutory limitations and public opinion, must be explicitly considered as these issues can significantly complicate the evaluation of predator control programs.

Figure 2. Conceptual framework for an integrated model of predator control



The sub-systems represent models of stand-alone systems that ultimately influence agricultural profitability within the integrated framework. The population dynamics sub-systems would include specie specific population growth models. These models, however, must be able to capture the relationships between individual species and the environment (e.g. forage for prey species), and relationships between species (e.g. predator-prey dynamics). Consider a simple model of coyote predation with two prey species, sheep and rabbits. Population models of each species in this simple model would need to relate changes in forage availability to population impacts on sheep and rabbits, which will impact coyote population dynamics and predation rates on each prey species. A model that excluded the population dynamics of rabbits in this system would likely overestimate the beneficial effects of predator control on sheep production. The oversimplified model would exclude the possibility that coyotes will substitute between alternative prey depending on availability.

The agricultural production sub-system would capture the agricultural decision making process. Standard farm level decision models (e.g. math programming) are well developed for this context (see Hazell and Norton, 1986). The agricultural decision model must explicitly account for livestock population dynamics, production response to alternative incentive programs and the effects of exogenous factors to fit in the integrated model. A farm level decision model that does not account for livestock population response to environmental changes would be difficult to integrate into the coyote example. The agricultural decision model must also be capable of modeling production response to alternative incentive programs and thus the relationship between alternative agricultural support programs and the effectiveness of predator control.

Support programs that provide incentives to increase livestock stocking rates, for example, may influence predator population dynamics and thereby affect the marginal benefits of predator control. Models that do not capture these complex relationships between incentive programs, incentive response, population dynamics and predator control may systematically misestimate the effectiveness of predator control for sustaining agricultural profitability.

The development of a framework that incorporates all of the components of figure 2 will require significant interdisciplinary cooperation. Biologists will need to collect data and build models of population dynamics, as well as conduct experiments on the biological effects of alternative predator control efforts. Animal scientists will need to build models of livestock population dynamics. Finally, economists must integrate these components into agricultural decision-making models. Factors key to the success of such a collaborative effort include the following: 1) the constituent models must be capable of capturing the effects of the full range of predator control and agricultural production inputs so that substitution possibilities and complementarities across inputs can be examined; 2) the effects of exogenous factors (e.g. weather) must be accounted for so that uncertainty can be explicitly modeled and so that the robustness of model conclusion can be tested under alternative scenarios, such as climate change; and 3) the constituent models must be developed in concert across disciplines so that they can be seamlessly integrated.

The integrated framework proposed here can serve as a long-term objective for researchers and policy-makers concerned with agricultural sustainability in the west. Interdisciplinary research of the scale required to develop this model, however, remain rare. Furthermore, integrating multiple dynamic models capable of being influenced by the same exogenous factors is highly sophisticated task. As a stop-gap researchers in each critical discipline can move forward independently in a manner consistent with the integrated framework. Each discipline only needs to consider the broader framework when designing research targeted to each sub-system. If each sub-system model includes variables and parameters that support linkages to other sub-systems, the integrated framework could evolve naturally.

The development of this integrated framework will require targeted, long-term research effort. The result, however, will be a model capable of eliciting the economic tradeoffs between alternative predator control activities at multiple scales and between predator control and alternative agricultural support programs. This will allow policy-makers to make informed decisions about the use of scarce resources and will allow the predator control debate to be analyzed in a new light.

Conclusions

Debates about the economic efficiency, biological efficacy and morality of predator control programs to protect agriculture are unlikely to be resolved in the near future. These programs, however, may be an important piece of comprehensive agricultural support programs that protect the sustainability of agriculture and the associated ecosystem services that agricultural lands provide. This view of predator control is fundamentally different than the perspectives represented in existing economic analyses of predator control. As a result, the evaluation of predator control as a component of agricultural land protection programs will require a new, more comprehensive and interdisciplinary, approach to predator control research. This new approach must explicitly integrate the population dynamics of predator and prey systems within an agricultural decision-making framework. In the absence of such research policy-makers will be unable to fully evaluate the efficiency of predator control programs relative to alternative agricultural support programs.

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