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Economic evaluation of beaver management to protect timber resources in Mississippi

Stephanie A. Shwiff, USDA/Wildlife Services' National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521 *stephanie.a.shwiff@aphis.usda.gov*
Katy N. Kirkpatrick, USDA/Wildlife Services' National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521
Kris Godwin, USDA/Wildlife Services, Mississippi State University, Starkville, MS 39762

***Abstract*:** It has become essential for groups involved with wildlife policy formulation and decision making to examine the economic benefits and costs derived from the management of nuisance wildlife species. Beavers (*Castor canadensis*) in Mississippi have seen significant population fluctuations over the last 150 years as their status has changed from a game species to protected species to nuisance species. The objectives of this study were to assess the beaver-caused economic impacts to the timber industry in Mississippi and estimate the damages avoided due to Mississippi's Beaver Control Assistance Program (BCAP) activities from 2005 to 2009. The total BCAP costs averaged $1.1 million annually over the study period. Analysis of 6 combinations of possible timber savings provided average annual direct program benefits that ranged from $25 million to $57 million. To estimate the potential secondary impact to the regional economy from these timber savings, an input-output model was utilized. The additional economic activity created in the region ranged from $19 million to $42 million. Using these estimated values of potential beaver damage, all calculated benefit-cost ratios indicated that BCAP was an economically efficient expenditure of resources. The economic methodology used herein can be applied to other integrated pest management programs to assess the economic efficiency of expenditures.

***Key words*:** beaver, *Castor canadensis*, benefit-cost analysis, economics, forestry resources, human–wildlife conflicts, Mississippi, wildlife damage management

Beavers (*Castor canadensis*) are large, aquatic rodents that have undergone dramatic population changes over the past 150 years (Figure 1; West and Godwin 2003). Prior to the 1850s, Mississippi had extensive beaver populations in all counties, and, during this time, beavers served as an important resource for humans. By the early 1900s, heavy trapping and hunting nearly caused extirpation of the species; however, legislation was passed in the 1930s to begin restoring beaver populations (Woodward 1983). Although exact population estimates are unavailable, the beaver restoration program was considered successful, and, by the 1980s, beavers had once again become abundant, which led to increased conflict with humans (Mastrangelo 1997, Swaford 2003). For example, beavers are the primary cause of considerable damage to timber in the southern United States because of their feeding activities and dam construction (Conover et al. 1995). Beavers girdle bark from trees and fell many trees (Figure 2). Additionally, beaver dams can cause flooding over large areas, making trees more prone to rot and disease. One beaver dam can flood and destroy thousands of hectares of timber, and flooding caused by beaver dams can also cause timber plantations to be inaccessible to harvesting equipment (Figure 3; West and Godwin 2003).

Several studies were undertaken in the 1960s to 1980s to characterize the nature and extent of monetary damage to timber in the absence of a beaver mitigation program. One study in Mississippi compared beaver-

Figure 1. Beavers (*Castor canadensis*) once served as an important resource for humans. (*Photo courtesy USDA Wildlife Services*)

Figure 2. Beavers kill trees by girdling them (left) and knawing them (right) until they fall. (*Photos courtesy USDA Wildlife Services*)

impounded areas in 1966 to 1967 to those in 1976 to 1977 and estimated that beaver-impounded areas increased 300% (Arner et al. 1969, Arner and Dubose 1978*a*). In 1978, the annual agricultural losses (including timber, crop, and beef production) due to beaver-flooding on these lands were estimated to be approximately $2.5 million (Arner and Dubose 1978b, Arner and Dubose 1979). Bullock and Arner (1985) determined that beaver damage to non-impounded marketable timber ranged from approximately $25 to $118 per hectare, which equated to potentially $215 million (in 1985 U.S. dollars) across Mississippi. As a result, beavers are currently managed to both alleviate damage and lessen conflicts with human interests. West and Godwin (2003) estimated that, even with beaver control, approximately $100 million in damage to public and private property occurs annually in the southeastern United States

In 1989, the Mississippi legislature created the Mississippi Beaver Control Advisory Board (Mastrangelo 1997). The advisory board was comprised of administrative heads from multiple government agencies with the goal of developing a program to control beavers on private and state-owned lands (Beaver Control Assistance Program [BCAP] 2006). In 1990, the BCAP was created. This integrated pest management (IPM) program was designed to control beaver damage and to provide relief to beaver-affected landowners rather than to eradicate beaver populations statewide. The U.S. Department of Agriculture's Wildlife Services (WS) state office in Mississippi was enlisted to assist in this effort due to their past history of beaver control efforts in the state. The primary focus of BCAP was beaver trapping on properties of interested landowners in participating counties. Additionally, WS personnel, who are trained and certified in the safe and effective use of explosives, routinely removed beaver dams from flooded property (WS 2007). Over the lifetime of the program, BCAP has operated in all 82 counties in Mississippi and received funding from 74 of them, with additional funding provided by state organizations, such as the department of transportation and Mississippi forestry commission. Although the program had been widely considered successful, no economic analysis of BCAP activities had previously been

Figure 3. Extensive beaver damage to Mississippi timber from flooding, feeding, and dam construction. (*Photo courtesy USDA Wildlife Services)*

performed. Our objectives were to estimate the monetary benefits of beaver damage mitigation to protect timber and additionally to conduct a benefit-cost analysis of program efforts to protect this natural resource.

Methods

To perform a benefit-cost analysis, we identified and compared the monetary benefits and costs of program actions. Mitigation of beaver damage was a non-marketed service, and we used the damage-avoided method to calculate its benefit (Loomis and Walsh, 1997). The value of timber resources protected was the assumed measure of the benefits provided by BCAP. BCAP began in 1990, and program cost data were available from 1990 to 2009. Unfortunately, data were not readily available on programmatic efforts until 2005. Hence, the study period for this analysis was limited to 2005 to 2009, and all monetary estimates were adjusted to 2009 USD at a 3% level of inflation.

Data collection

Data were obtained from the WS-Mississippi Management Information Systems (MIS) database and relevant literature (Arner and Dubose 1979, Bullock and Arner 1985). Annual records of wildlife management activities were kept as part of the WS-Mississippi program actions using the MIS system. Each WS specialist collected and recorded wildlife damage management information for each reported incident, including the value of the resource damaged by the offending species. These estimates reflect the replacement value of the resource as directly estimated by the landowner, or, occasionally, by WS specialists. Data was recorded for both direct control activities and technical assistance (i.e., consultation advice or brochures).

Direct benefits

To determine the Mississippi forestry industry's savings that resulted from BCAP activities, we made several calculations. First, we identified the amount of resources damaged by beavers in Mississippi. Second, we predicted the amount of damage that would have occurred in the absence of the program. Finally, we subtracted the actual amount of damage to timber from the amount of predicted damage, to determine overall savings.

The annual total benefits equal timber savings due to beaver damage was expressed as:

$$Timber_{saved}^{ijk} = (Timber_{m}^{i} + Timber_{n}^{j}) - Timber_{a}^{k} \quad (1)$$

The first portion of the right hand side of the equation in parentheses describes the estimation of impounded and nonimpounded timber damage in the absence of BCAP. The variable

$Timber_m^i$ represents the estimated level *i* (e.g., high or low) of impounded timber damage without BCAP, and $Timber_n^j$ represents the level *j* (e.g., high or low) of nonimpounded timber damage in the absence of BCAP. The current or actual level *k* (e.g., minimum, mean, maximum) of beaver damage $Timber_a^k$ is the last variable in equation 1 and indicates the level of beaver damage that occurs even with the operation of the BCAP. Therefore, the calculation of the value of timber saved $Timber_{saved}^{ijk}$ attributable to the BCAP results from subtracting the actual or current level of damage with the BCAP ($Timber_a^k$) from the estimated level of damage that would have occurred in the absence of the program $Timber_m^i = Timber_n^j$.

Recent literature regarding the level of beaver damage to timber in Mississippi in the absence of a beaver control or management after the introduction of BCAP in 1990 is nonexistent. BCAP offers beaver control assistance in all 82 counties of Mississippi, making a study estimating the level of beaver damage in the absence of control virtually impossible (Swaford 2003). Therefore, in order to project the annual amount of timber damage that could have occurred in the absence of BCAP, we referenced published estimates of beaver damage to timber in Mississippi without beaver control or management from studies prior to 1990 (Arner and Dubose 1979, Bullock and Arner 1985). This literature afforded a range of damage estimates, from both impounded and non-impounded timber, to provide a total projected amount of beaver damage in the absence of an IPM program.

Economic values of beaver damage from impounded timber ($Timber_m^j$) were calculated from Arner and Dubose (1978*b*). The researchers inventoried beaver impoundments 0.4 hectares and larger in Mississippi to determine the average impoundment period and proportions of flooded land that was hardwood, pine, cropland, and pasture. The researchers estimated the amount beaver impounded timber to be 22,908 ha of hardwood and 438 ha of pine, recorded in saw-timber or pulpwood volume measurements for valuation. We converted these volume measurements into weight measurements because the forestry industry has since changed methods of measurement to standardize production (Mississippi State University Extension Service 2009*a*, 2010*a*, 2010*b*). Once converted, we calculated the current monetary value using an average timber price by volume in Mississippi for all 4 quarters by type in 2009 (Mississippi State University Extension Service 2010*c*). Because recorded damage occurred over multiple years, we divided calculated damage by the number of years over which it had occurred, following Arner and Dubose (1979).

Beaver damage estimates for nonimpounded timber ($Timber_n^j$) were also calculated from previous research by Bullock and Arner (1985). In this research study, 6 study locations containing merchantable timber within floodplains were selected and cruised at right angles to stream flow. Tallies were made of all woody species >1 in diameter at breast height, recording multiple variables including beaver damage. Bullock and Arner (1985) estimated that at a 95% confidence interval, the average damage to nonimpounded timber ranged of approximately $35 to $98 per ha of bottomland forest. Following their methodology, we applied the lower bound estimate to the total ha of bottomland forests of saw-timber and pole-wood size in Mississippi (Missisippi State University Extension Service 2009*a*, Oswalt et al. 2009) and calculated an additional damage level of 50% of the lower bound. Because the recorded damage occurred over multiple years, we then divided the calculated damage by the number of years over which it had occurred. The estimated value (low and high) of impounded plus nonimpounded timber damage represents the total potential damage in the absence of BCAP ($Timber_{saved}^{ijk}$; Arner and Dubose 1979, Bullock and Arner 1985).

The amount of actual damage ($Timber_a^k$) was taken from MIS records. Three values were utilized: the minimum, mean, and maximum reported timber damage in Mississippi from 2005 to 2009. The difference between ($Timber_m^i = Timber_n^j$) and $Timber_a^k$ represents the annual savings resulting from BCAP protection of timber. Prediction of the total benefits of BCAP, therefore, involved comparing the actual minimum, mean, and maximum levels of reported damage to the low- and high-projected estimates of damage, which provides a range of potentially prevented beaver damage.

Additional benefits

The loss of the value of timber due to beaver damage in Mississippi creates additional economic impacts as that loss ripples through the economy. Preventing those losses, therefore, represents a savings or benefit to the economy and can be measured using certain economic models. There are 3 types of regional economic impacts of timber savings to be measured: direct, indirect, and induced. All of these can be measured in terms of income and jobs saved. Measurement in terms of income represents the regional equivalent of gross domestic product (GDP). One type of direct economic impact is the impact to revenue experienced by timber producers, in this case, represented by revenue savings measured in terms of the value of timber saved ($Timber^{ijk}_{saved}$). Direct economic impacts also are known as primary impacts, which create secondary (e.g., indirect and induced) impacts, commonly known as the multiplier effect, in the Mississippi economy.

For example, preventing losses to timber producers increases their income and ability to purchase inputs into the production process. This implies an increase in income for other businesses that provide those inputs, which is the secondary economic impact of the timber savings. The indirect benefit is that when income associated with these supplying businesses increases, more is spent on other goods and services (e.g., restaurants, car repair, etc.). Thus, income associated with those businesses also increases. This is the induced benefit. All these effects are summed to give the total impact, indicating that when losses are avoided due to the BCAP, the entire economy benefits. To estimate these effects requires the use of sophisticated input-output computer modeling software.

We used the IMPLAN (IMpact Analysis for PLANning) model to estimate the secondary economic impacts. IMPLAN is an input-output model of the regional economy based on the known linkages between various sectors (Jones 1997). IMPLAN was born out of the need to examine the economic impacts on timber, range, mining, and recreation from the 1976 National Forest Management Act and the USDA forest service's creation of 5-year management plans. The U.S. Forest Service in conjunction with the University of Minnesota first developed the IMPLAN model to estimate these impacts (MIG Inc. 2010). Currently, the IMPLAN modeling software is the most widely used input-output economic modeling software in private industry and state and federal governments because of its flexibility and the extensive economic information that may be obtained through its application (Shwiff et al. 2010, Weiler et al. 2002, Henderson and Munn 1998).

A slight modification to equation 1 allows for the incorporation the secondary or multiplier effects estimated by IMPLAN:

$$Timber^{ijk}_{saved} = \left[(\hat{Timber}^{i}_{m} + \hat{Timber}^{j}_{n}) - Timber^{k}_{a} \right] \times \alpha \quad (2)$$

Equation 2 indicates that the total value of timber saved is now a function of the estimated direct value of impounded and nonimpounded timber saved (the portion of the equation in brackets) increased by the multiplier derived from the IMPLAN model.

Costs

We determined the cost of BCAP using the average program expenditures during the study period from 2005 to 2009 (in 2009 U.S. dollars). In the decade from 1990 to 1999, the annual average cost of the program was approximately $800,000, and, in the second decade, from 2000 to 2009, the annual average cost increased to about $1.2 million. The average total cost (TC) of the program during the entire study period was $1.1 million. These costs reflect the entire BCAP cost and were not separated by protected resource; that is, funding from other agencies included in the budget that were used for other areas of protection (e.g. roads and bridges) were not removed from the calculations because of data limitations. This can be seen as overstating the costs for beaver management to protect timber, making the results of this analysis potentially conservative.

Benefit-cost ratios

Benefit-cost ratio for BCAP were derived using the total benefits (TB), the direct, indirect, and induced benefits ($Timber^{ijk}_{saved}$), and the average total costs of BCAP. The benefit-cost ratios were calculated using the standard format of the ratio of benefits to costs (Boardman et al. 1996; Loomis and Walsh 1997).

The benefit-cost ratios were calculated using the following formula:

$$BCR = \frac{TB}{TC} = \frac{Timber^{ijk}_{saved}}{Expenditures}$$

A benefit-cost ratio of 1.0 would indicate that the benefits and costs were equal, or, in other words, 1 unit of cost yields 1 unit of benefits. A benefit-cost ratio >1.0 would indicate that the benefits of BCAP outweighed the costs and that the monies allocated were economically efficient.

Table 1. Number of incidents, total and average timber damage by beavers in Mississippi recorded in WS-MS MIS records (2005–2009) in 2009 U.S. dollars.

Year	Number of incidents	Total damage ($)	Average damage ($)
2005	358	2,981,799	8,329
2006	362	3,060,914	8,456
2007	366	4,903,374	13,397
2008	324	6,967,384	21,504
2009	265	2,050,465	7,738

Results

In the 5 years of records that we examined (2005 to 2009), WS's MIS data indicated 1,675 beaver damage management incidents involving timber (Table 1). Records show that 2009 was the lowest total value and average damage amount per incident year; that is, it was the year in which the greatest amount of damage suppression occurred during the study period. Alternately, 2008 represents the highest reported beaver damage year for timber. The damage amount per incident increased over time except for in 2009, despite all figures being adjusted to 2009 U.S. dollars.

We calculated the lowest amount of direct savings (program benefits) to accrue under the low estimate of projected timber damage (approximately $32 million) minus the actual maximum level of damage reported with control (approximately $7 million) for a value $25 million in protected timber (Table 2). Additional indirect and induced benefits from economic activity created by this protected timber was calculated using the IMPLAN model, equaling approximately $19 million and a minimum of 126 saved jobs (Table 3). This indicates that, under the most conservative scenario, Mississippi received a minimum savings of approximately $44 million and 126 jobs due to BCAP activities, resulting in an overall multiplier (α) of 1.74 (Table 2).

When the estimated benefits were compared to the average costs of the program, the potential ratios of benefits to costs were determined. In this analysis, the BCRs ranged from 39.67 to 88.52 (Table 3). This indicates every dollar spent on BCAP saves between $39.67 and $88.52 in potential beaver damage to timber and the state economy.

Discussion

The forestry industry is especially important in the southern part of the United States and

Table 2. Estimated number of jobs saved and direct, indirect, and induced annual benefits of the Beaver Control Assistance Program (BCAP) in Mississippi (2005–2009) in 2009 U.S. dollars.

Potential damage		Actual damage		
		Maximum ($)	Mean ($)	Minimum ($)
Low estimate	Direct	25,398,252	28,372,848	30,315,170
	Indirect or induced	18,809,530	21,012,470	22,450,920
	Jobs (number)	126	141	151
	Total Benefits	44,207,782	49,385,318	52,766,090
High estimate	Direct	51,759,359	54,733,955	56,676,277
	Indirect or induced	38,332,130	40,535,070	41,973,520
	Jobs (number)	258	272	282
	Total benefits	90,091,489	95,269,025	98,649,797

Table 3. Benefit-cost ratios of BCAP protection of timber (2005–2009).

Potential damage	Actual damage		
	Maximum	Mean	Minimum
Low estimate	40	44	47
High estimate	81	85	89

can have significant impacts on the regional economy (Missisippi State University Extension Service 2009*a*). This industry is linked to many other regional industries in terms of input and output demands for primary and secondary production of timber-related goods (Henderson and Munn 2008). These linkages were captured by the input-output analysis conducted in this study. It is of interest to note that the estimated monetary value of potential direct damage caused by beavers in the absence of BCAP, low and high estimates, make up between approximately 4% and 7%, respectively, of the total delivered value of timber in Mississippi (Missisippi State University Extension Service 2009*b*).

It is important to note that in 2009 the United States was in the midst of a housing market crisis, causing both an extensive drop in residential construction across the country and global economic recession. Therefore, the prices used to value timber (average prices reported in 2009) were much lower than prices from the same period in 2005 when housing construction was at recent highs (Missisippi State University Extension Service 2009*a*). This lower valuation of timber greatly influences the final savings estimate of BCAP.

There are several limitations associated with this study. First, the use of data from the 1970s and 1980s regarding beaver damage to timber in the absence of control does not account for changes in beaver populations, management strategies, and land use that might impact the current applicability of this data. However, since this is the only data available detailing pre-BCAP damage levels in Mississippi, we utilized this data within a range in an attempt to decrease some of the uncertainty surrounding their use. Future studies should be designed to assess the current level of beaver damage without control or varying levels of control in an effort to better measure the effectiveness of different beaver management techniques. Second, IMPLAN is a temporally static model; that is, it accounts for impacts within only a single year. Timber is a multiyear crop that, for this analysis, was artificially measured annually. The use of dynamic economic models that could better account for multiyear crops would perhaps provide better insight into protecting timber from beaver damage and the impacts to the greater economy. Funding limitations prohibited the use of these models for this analysis.

This retrospective examination of Mississippi's program to control beaver damage determined that the program was economically efficient. The benefit-cost analysis confirmed the effectiveness of beaver damage mitigation for timber production, one of the most frequent resources protected in Mississippi. Economic analysis of wildlife management is often difficult because data are limited or the protected resources are virtually impossible to value (i.e., preventing a road from being flooded and the decreased possibility of human injury or damage to personal vehicles, etc.). Due to this fact, we intentionally sought to estimate the benefits of BCAP protection of timber conservatively. The choice of the appropriate actual versus projected damage to determine the benefits of the program depend on a suite of factors, including urbanization, loss of habitat, beaver population densities, reinvasion rates, and other factors. Therefore, a range of potential timber damage in the absence of control was estimated and compared to the cost for the entire BCAP. This proved useful; however, we recommend incorporation of more resources protected into a benefit-cost analysis when feasible, which would likely increase the projected efficiency of BCAP activities.

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STEPHANIE A. SHWIFF is the economic research of human–wildlife conflicts project leader at the USDA/APHIS/Wildlife Services' National Wildlife Research Center. She received her Ph.D. degree from Colorado State University and has taught numerous undergraduate courses in economics at Colorado State University and Colorado School of Mines.Her research interests, publications and presentations involve wildlife damage management economics, resource valuation techniques, and the economics of environmental management, with an emphasis on the use of benefit-cost analysis and econometrics. Her leisure activities include coaching youth soccer, mountain biking and backpacking.

KATY N. KIRKPATRICK is a biologist within the economic research of human–wildlife conflicts project at USDA/APHIS/Wildlife Services' National Wildlife Research Center where she provided research support since 2003. She received her B.S. degree from Colorado State University. Her research interests include human dimensions of natural resources and applied economic analysis of human–wildlife conflicts and wildlife management. She enjoys rock climbing and hiking, and she is active in retired greyhound rescue.

KRIS GODWIN has been state director for the Mississippi USDA/APHIS Wildlife Services program since 1999. She oversees the Mississippi beaver control assistance program, and she works with airports, state and federal agencies and nongovernment organizations on wildlife damage management issues. She is an adjunct assistant professor at Mississippi State University and is the current president of the Mississippi Wildlife Federation. She holds an AAS degree in biological technology from State University of New York (SUNY)–Cobleskill, a B.S. degree in wildlife ecology from SUNY College of Environmental Science and Forestry–Syracuse, and an M.S. degree in wildlife management from Mississippi State University. She is married to Dave Godwin, who is the Mississippi state turkey program coordinator. They have 2 children, daughter Brannon and son Eric.