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The Role of Bounties and Human Behavior on Louisiana Nutria Harvests

Cheikhna Dedah, Richard F. Kazmierczak, Jr., and Walter R. Keithly, Jr.

In response to nutria-linked degradation of much of its coastal wetlands, Louisiana established the Coastwide Nutria Control Program (CNCP) in January 2002. CNCP instituted, among other things, an "economic incentive payment" of $4.00 per delivered nutria tail from registered participants in the program. To examine whether this bounty has had an impact on nutria harvest and whether alternative bounty levels can, in general, generate additional harvesting activities, we developed a bioeconomic supply model that relates Louisiana's annual nutria harvests to a suite of economic and environmental factors. Results suggested that the annual nutria harvest is responsive to both the price received per animal and costs. Results also suggested that the nutria harvest has increased as a result of the bounty, but that the initial bounty of $4.00 per tail may be insufficient to achieve the state's goal of harvesting 400,000 animals per year but that a bounty equal to $5.00 per tail would likely achieve the stated goal.

Key Words: bounties, long-run supply, nutria, open access

JEL Classification: Q210

Nutria (*Myocastor coypus*) is a large, semiaquatic rodent native to South America that was introduced to Louisiana in 1938 for farm-based fur production purposes (Lowery, 1974; Nowak and Ernest 1991). Shortly after its introduction, a small number were either intentionally released and/or escaped into the coastal marshes. Having few natural predators in its new environment, nutria populations expanded rapidly and, together with demand for their fur pelts, led to the establishment of a viable commercial trapping industry by the late 1940s (Lowery, 1974). This trapping pressure is thought to have kept nutria populations at levels consistent with the long-run carrying capacity of the coastal marshes where nutria fed on the root structures of aquatic vegetation. Encouraged by market prices for fur pelts in Europe and the subsistence economy of many coastal Louisiana communities, harvests of nutria ranged from 1 to 2 million pelts annually for much of the 1960s and 1970s (Figure 1) (Marx, Mouton, and Linscombe, 2004).

The demand for nutria pelts, and thus pelt prices, began to decline in the early 1980s with

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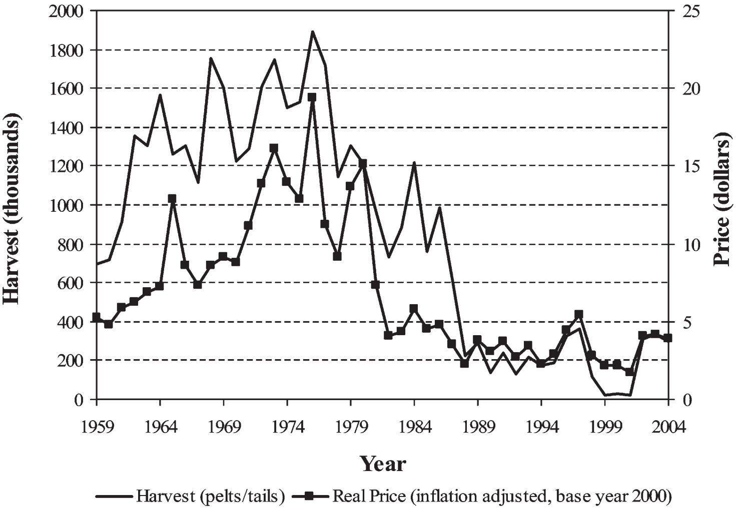

Figure 1. Annual Nutria Harvest and Average Real Price per Pelt from 1959 to 2004

the emergence of strong antifur campaigns in Europe and the United States, the increasing acceptance of synthetic fur products, and relatively mild winter conditions in many traditional fur-importing regions (Figure 1) (Louisiana Department of Wildlife and Fisheries, 2005). Nutria harvests declined from an average of 1.5 million pelts annually in the 1970s to an average of 790,000 pelts annually during the 1980s, only to be followed by a further decline in the 1990s to an average annual harvest of 190,000 pelts. By the turn of the century, nutria harvests had fallen to less than 30,000 pelts annually. This greatly reduced trapping pressure, in conjunction with nutria's high reproductive rate and lack of predators, led to population increases and range expansion, followed by foraging-linked degradation of many coastal wetlands. For example, a 2001 aerial survey estimated that more than 83,000 coastal acres were damaged by nutria, a figure considered conservative as the aerial surveys were only capable of detecting severe damage (Marx, Mouton, and Linscombe, 2004).

In response to this nutria-inflicted wetland damage, Louisiana established the Coastwide Nutria Control Program (CNCP) in January 2002. Supported by funds from the U.S. Coastal Wetlands Planning, Protection, and Restoration Act, CNCP instituted an "economic incentive payment" of \$4.00 per delivered nutria tail from registered participants in the program. The official program goal was to "encourage the harvest of up to 400,000 nutria annually from coastal Louisiana" (Louisiana Department of Wildlife and Fisheries, 2005). In this paper we present a framework for analyzing the potential role of bounties in controlling an invasive vertebrate species (i.e., nutria) under conditions where native environmental assets are severely threatened and direct management response is hampered by budgetary, personnel, and geographic constraints. To do so, we developed a bioeconomic model of nutria harvesting in Louisiana and use the model to estimate expected change in harvests associated with introducing various monetary incentives (i.e., bounties).

Modeling Considerations

The economic literature on the management of renewable resources emphasizes the need to examine the supply-side relationships between harvests and harvesting effort, with the ultimate goal of linking harvest effort to the total, average, and marginal costs of harvesting. Based on this body of literature, if a renewable resource is privately owned, the long-run supply (harvest) is determined by the marginal cost of harvesting at different output prices. Since any sustained amount of effort beyond that needed to harvest maximum sustainable yield[1] (MSY) would result in a reduction in harvest and, hence, revenues and profits, the supply curve under a private ownership regime will be, according to theory, strictly upward sloping, approaching MSY asymptotically (Bell, 1978).

In the case of open-access resources, however, individual harvesters do not have an incentive to manage the resource for profit maximization as entry into the harvesting activity and over-harvesting cannot be controlled. To account for this behavior, Copes (1970) developed a theoretical model that directly related cost as a function of harvest rather than of harvesting effort, thereby generating a long-run supply (harvest) curve that has a backward bending shape at prices higher than that needed to attract the amount of effort associated with MSY. Under this open-access model, long-run supply is determined by the average cost of harvesting at different output prices. Long-run harvest increases with increases in output price up to the point where harvest equals MSY. Prices higher than that needed to attract an amount of effort to harvest MSY result in a decline in supply (harvest) due to declining stocks (Clark, 1976; Copes, 1970; Hartwick and Olewiler, 1986).

The theoretical relationship between the supply curve of a renewable resource under a private ownership regime (labeled MC^0) and the supply curve of that same resource under open-access regime (labeled AC^0) is illustrated in Figure 2. As indicated, under the open-access regime, the supply curve is backward bending at output prices beyond that necessary to attract a level of effort needed to harvest MSY (i.e., any output price greater than P^{MSY}). This feature, as noted, is the outcome of the lack of ownership of the resource and, hence, the ability to manage the resource for profit maximization. Given the ability to manage the resource for profit maximization under a private ownership regime, the supply curve becomes vertical as MSY is approached because any level of effort in excess of that required to harvest MSY would result in a reduction in long-run harvest and, hence, profit. Finally, while not shown in Figure 2, increases (decreases) in industry input costs (e.g., the cost of labor or capital) will, according to theory, result in a upward (downward) shift in the respective long-run supply curves, implying that a higher output price would be required to achieve any given long-run harvest.

Although the theoretical models sharply distinguish between private ownership and open access property rights, the distinction, in practice, can be somewhat "clouded." This is particularly the case with respect to the Louisiana nutria resource where harvesting activities take place under a mixed property rights structure. Trapping mostly occurs on private lands where landowners have exclusive rights to any activities on their property. Trappers are required to buy trapping permits from the state and the harvesting season is limited to late-November through late-February each year. Each of these factors tends to limit the total amount of trapping effort, thus giving nutria some characteristics of a private resource. However, the movement of nutria between properties, the relatively small levels of investment required in equipment, and knowledge for trapping suggest that trapping effort is capable of expansion beyond MSY, implying that nutria have common property characteristics as well.[2] Finally, being an invasive pest in the coastal ecosystem, nutria can, as mentioned, inflict significant wetlands degradation. To the extent that this degradation reduces the income-generating potential of the property, it may be in an owner's best interest to harvest beyond MSY.

Given the above stated characteristics associated with Louisiana nutria and harvesting activities, it was hypothesized that the long-run nutria supply curve could best be represented by the open-access model for a renewable resource. For purposes of analysis, the number of nutria harvested H is defined as a function of pelt price P, trapper opportunity cost OC, and a vector of environmental variables E:

[1] Maximum sustainable yield is generally defined as the largest annual catch or yield that can be taken from a stock under existing environmental conditions.

[2] In addition, about one-quarter of the coastal wetlands are publically owned (by either the state or federal government). Trapping is permitted on a portion of these public grounds.

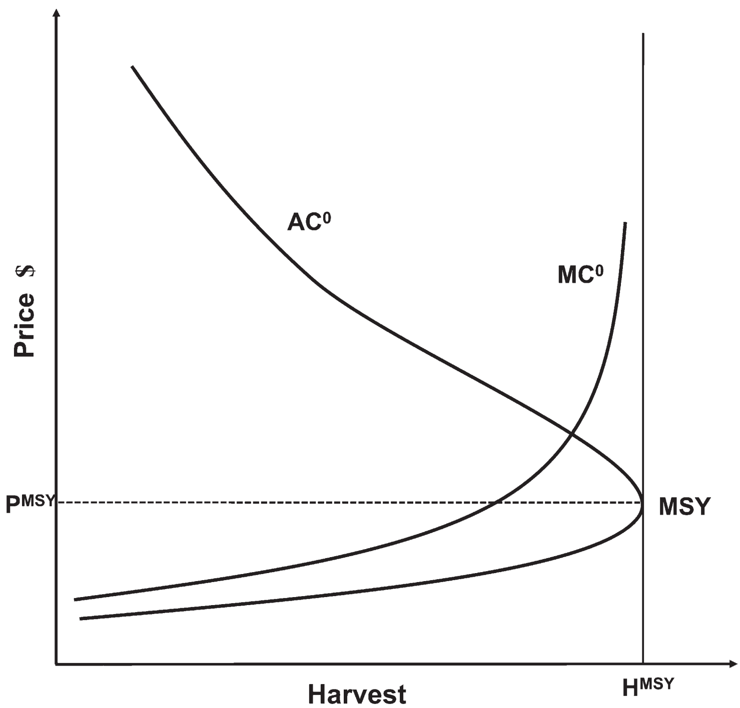

Figure 2. Hypothetical Long-run Supply Curve for a Renewable Resource Under Open Access and Private Property Regimes

(1) $H = f(P, OC, E)$.

The role of pelt price[3] and opportunity costs in determining harvest can be hypothesized by appealing to economic theory. In the case of nutria being an open-access resource, increases in pelt price would be expected to positively affect harvest up to MSY, and thereafter negatively affect harvest as biological constraints reduce the number of animals available for harvest. The effect of trapper opportunity costs, or the value of what a trapper is giving up to engage in trapping, is also economically unambiguous, with higher opportunity costs leading to lower harvests. These hypothesized economic relationships are fully testable within the modeling framework.

Hypothesizing the role of environmental variables in determining harvest levels cannot be done with reference to economic theory, but instead depends on the specific environmental variables chosen, how they are defined, and what is known about their relationship to the stock of nutria. Three environment-related variables were used in the estimations—measures of wetland acres, cold weather, and alligator predation. Nutria are generally herbivorous, eating 1.13–1.59 kilograms of vegetative matter daily (Evans, 1970). In addition to serving as a feeding site, wetlands also are prime breeding and nursery grounds. As a result, wetland acreage is expected to be positively related to nutria abundance and, hence, nutria harvests. Cold weather, however, is one of the major factors limiting nutria abundance and distribution in temperate regions due to reproductive failure and direct mass-mortality (Gosling, Baker, and Skinner, 1983; Newson, 1966; Reggiani, Boitani, and De Stefano, 1995). For example, the severe winter of 1962 was found to have a significant mortality effect on the

[3] One might question whether price should be an independent or dependent variable in the model, as changes in price are likely to influence long-term harvests but, in certain situations, changes in long-term harvests may also influence price (thus suggesting the need to estimate harvest and price in a simultaneous equation framework). This later situation does not appear to apply to the current study as Louisiana's nutria supply constitutes a small share of the world supply and, as such, changes in Louisiana harvests are unlikely to significantly affect world pelt price.

Louisiana nutria population and morbidity effects on surviving animals as evidenced by missing tails and feet (Lowery, 1974). Thus, the cold-weather variable is hypothesized to be negatively related to nutria harvest. Lastly, alligators have become major predators of nutria in Louisiana. For example, Valentine et al. (1972) found nutria remains in 56% of alligator stomachs, while Wolfe, Bradshaw, and Chabreck (1987) concluded that approximately 60% of alligator diets by weight consisted of nutria. As a result, it was hypothesized that increases (decreases) in alligator populations lead to decreases (increases) in nutria harvests due to the effects of predation on nutria stocks.

Given the general relationships described above, the long-run nutria supply curve was estimated based on the following model[4]:

$$\ln(HH)_t = \beta_0 + \beta_1 \cdot \ln P_t + \beta_2 \cdot P_t + \beta_3 \cdot OC_t + \beta_4 \cdot alligator_t + \beta_5 \cdot freeze_t + \beta_6 \cdot cncp + e_t \tag{2}$$

where $\ln(HH_t)$ is the natural logarithm of harvest quantity per hectare of coastal wetlands in year t, P_t is the deflated pelt price received by trappers in year t, OC_t represents the opportunity cost measured by the annual unemployment rate in year t for six coastal parishes in Louisiana, $alligator_t$ is the estimated number of alligator nests in year t (in thousands), $freeze_t$ represents a winter severity index in year t, *cncp* is a binary variable indicating the years (2002–2004) in which the Coastwide Nutria Control Program was operating[5], and e_t represent the estimation error term. Harvest per hectare (HH_t) was used as a dependent variable due to the high degree of collinearity in the data for wetlands coverage and alligator nests, thus necessitating the elimination of one of those factors from the explicit vector of independent variables.

Data and Estimation Procedure

Data used in this analysis are annual time series data covering the period 1960–2004.[6] In total, 45 observations were used in the analysis. Pelts harvested and the nominal price received by trappers were collected from data maintained by the Louisiana Department of Wildlife and Fisheries, with nominal prices deflated using the U.S. Bureau of Economic Analysis and Statistics implicit price deflator (base year 2000). The price used for estimation purposes included the average price paid to the harvesters for pelts which were sold plus any bounty received for the harvested product.[7]

Coastal wetland coverage, a value that has not been consistently measured over the study time period, was calculated with 1968 as a base year and using Turner's (1997) estimated annual wetland loss values to determine cumulative losses through any given year.[8] Unemployment rates, used to develop the index of opportunity costs, were from the six coastal Louisiana parishes (Plaquemines, St. Bernard, Terrebonne, Vermilion, Calcasieu, and Cameron) having the majority of nutria harvests. The annual average unemployment rate for 1970–2001 was calculated by summing the number of unemployed in the six-parish area and dividing by the sum of

[4] For comparison purposes, the following private–property rights based model was also estimated: $\ln(HH)_t = \beta_0 + \beta_1 \cdot \frac{1}{P_t} + \beta_2 \cdot OC_t + \beta_3 \cdot alligator_t + \beta_4 \cdot freeze_t + \beta_5 \cdot cncp + e_t$. While results associated with this model are not discussed in the paper, they were, in general, not significantly different from the results associated with the open–access regime model.

[5] This binary variable is used as a supply shifter in the equation. Specifically, registered participants in the CNCP were given the option of using firearms in lieu of traps when taking nutria. The variable *cncp* is included in the analysis in an attempt to "capture" the expected difference in cost per unit harvest between firearms and traps and any effect this difference may have on supply.

[6] The Louisiana nutria trapping season runs from November through February of the following year, with the reported harvest and prices received spanning the calendar year change. For purposes of this study, the data were attributed to the year in which the trapping season started (e.g., data for the November 1960 to February 1961 season is referred to as the 1960 data). Given significant displacement of many nutria trappers due to 2005 hurricanes, the analysis has been extended till 2004.

[7] Because the bounty is relatively high compared with the pelt price in recent years, some participants in the program collected the bounty but did not sell the harvested pelts.

[8] Total coastal Louisiana wetlands in 1968 were estimated to be 3,858,082 acres (Louisiana Wildlife and Fisheries Commission (1970)).

Table 1. Parameter Estimates for Nutria Supply Model

Variable	Parameter Estimate	Standard Error	p-value
intercept	−4.7944	0.4114	<0.0001
ln(price)	2.5828	0.2974	<0.0001
price	−0.1792	0.0386	<0.0001
opportunity cost	0.1129	0.0242	<0.0001
alligator	−0.0174	0.0060	0.0064
freeze	0.0025	0.0025	0.3247
cncp	0.5584	0.2654	0.0422
DW = 1.80	SSE = 3.0191	MSE = 0.0816	$R^2 = 0.948$

the civil labor force in those locations. The average state unemployment rate was used as a proxy from 1960 through 1969 because parish-level data were unavailable prior to 1970. Overall, the annual unemployment rate, which averaged 7.4% during the period of analysis, ranged from a low of 4.3% in 1966 to a high of more than 15% in 1986.

Although an annual estimate of alligator numbers was not available for our study, the Louisiana Department of Wildlife and Fisheries, using aerial surveys, has collected data on the number of alligator nests since 1971 (Newsom, Joanen, and Haward, 1987). Kelly (2004) estimated that the alligator population recovery rate was approximately 13% in the 1971–1972 period, and this rate was used to back-calculate number of nests from 1960 through 1970. The resulting 1960–2004 time series of alligator nests was used as a proxy for alligator predation on nutria in the estimations. Overall, the number of nests averaged about 19 thousand annually and ranged from about 1.5 thousand in 1961 to almost 50 thousand in recent years.

The winter severity index was calculated from meteorological data (New Orleans Audubon Weather Center, National Oceanic and Atmospheric Administration) using the Reggiani, Boitani, and De Stefano (1995) modification of the Gosling, Baker, and Skinner (1983) formula:

$$freeze = \sum_{i=0}^{n} x_i^2 \tag{3}$$

where i is a run of successive freezing days (24 hours period where minimum temperatures do not exceed 0° Celsius) in the winter season, x is the length of the run, and n is the number of runs in a winter season. The index, which averaged 15.04 annually during the study period showed a high degree of variability with a range from 0 to 64.

The supply model expressed in Equation (2) was estimated over the 1960–2004 period of study using Proc Autoreg procedure in the SAS software package. The value of Durbin-Watson test suggested that first order serial correlation might be a problem, which was corrected using NLAG option in Proc Autoreg.

Empirical Results

The parameter estimates of the model after correcting for first-order serial correlation are presented in Table 1. The explanatory power of the model was high with about 95% of the variation in the dependent variable being explained by the suite of explanatory variables included in the analysis. All estimated parameters except for the one associated with the variable *freeze* were significant at 5% level of significance, and in-sample predictions using the estimated model appear to adequately describe the observed nutria harvests over the period of analysis (Figure 3). To evaluate the robustness of the model to the time framework, the supply model was estimated using data covering the period 1970–2004.[9,10] In general,

[9] The data analysis for this paper was generated using SAS software, Version 9.1 of the SAS system for Windows. Copyright © 2009 SAS Institute Inc.

[10] Robustness of the model results to starting date was examined, in part, because of the missing data in the earlier years on unemployment rates by parish and alligator populations.

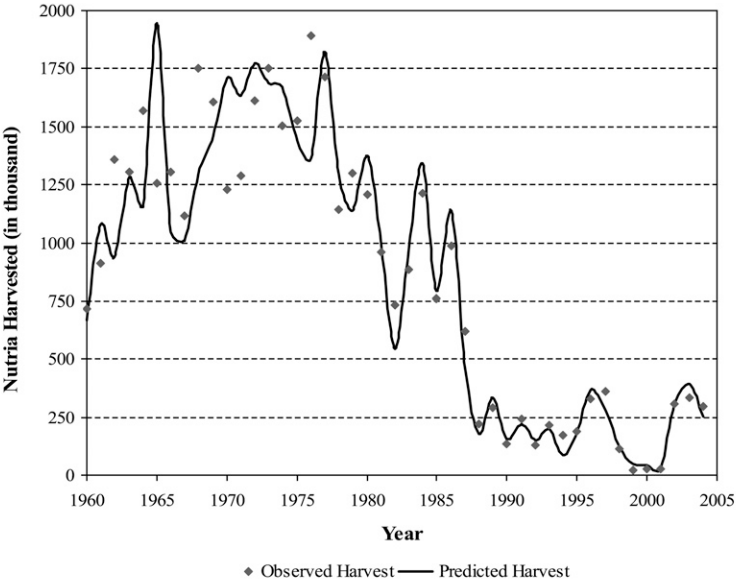

Figure 3. Observed and Predicted Annual Harvests

parameter estimates were stable regardless of the timeframe used for analysis.

The negative parameter estimate on the variable *price* and positive parameter estimate on the variable *ln(price)* indicated that harvests initially increase as price increases, but at a decreasing rate. For price increases beyond a point, harvests will begin to fall as the influence of the negative parameter is outweighed by the influence of the positive parameter estimate. Thus, data used for the estimated model do reflect the hypothesized backward-bending supply curve that might be expected in an open-access resource, and the point where it begins to bend backward being equal to MSY. Beyond the price variables, the positive sign on *opportunity cost* indicated that as unemployment rises, the cost of expending labor on trapping activity falls, thus increasing trapping effort and nutria harvests (up to MSY). Similarly, the negative sign associated with the *alligator* variable is consistent with the hypothesis that increases in alligator numbers, increases the predation rate on nutria, thereby reducing nutria stock available for harvest. The significance and positive magnitude on the parameter estimate for *cncp* indicated that the change in regulation that provided increased flexibility with respect to permissible harvesting methods resulted in an increase in harvest; likely the result of a reduction in cost per unit harvest.

The estimated elasticities (calculated at the sample means) for all continuous variables in the model and their associated standard errors are reported in Table 2. All elasticity estimates are statistically significant at 5% level of significance and exhibit the expected signs. A 1% increase in price per pelt that the trappers received was found to result in 1.34% increase in the long-run harvest of nutria. Similarly, a 1% increase in the unemployment rate (*OC*) was associated with a 0.83% increase in the long-run nutria harvest. Finally, a 1% increase in alligator population will result in a 0.34% decrease in the long-run nutria harvest, *ceteris paribus*.

Table 2. Elasticity Estimates for Nutria Supply Model

Variable	Elasticity Estimate	Standard Errors
Price	1.34	0.098
Alligator	−0.335	0.107
Opportunity Cost	0.834	0.126

Discussion

As stated by Bax et al. (2003) "[s]cientists and policy makers increasingly see the introduction of alien species as a major threat to marine biodiversity and a contributor to environmental change." The authors further state that as such. . . "management responses need to cover a diverse range of human activity." While the use of bounties has been criticized for both its efficacy and ethical implications, monetary incentives do have the potential to encourage specific types of harvester behavior and, in particular, may encourage the harvesting of invasive species that cause significant environmental damage in their adopted habitat (Bulte and Rondeau, 2005). The goal of protecting coastal and marine environments from invasive species avoids many ethical and moral hazard questions associated with the historical use of bounties because economic incentives are specifically designed to promote overall environmental management objectives. For such policies to be effective, however, bounties need to be appropriately structured and implemented, and this requires information on how human agents will react to different bounty levels.

Having controlled for environmental factors, the estimated models suggested that Louisiana nutria trappers responded to economic factors, including monetary incentives. As suggested by theory, increasing prices had a positive influence on harvest (up to MSY) while opportunity costs exhibited a negative influence.

The statistical significance of the model suggested that the model can be used to forecast the relationship between harvests and prices for given values of other variables in the model. Under the assumption of open access scenario, the long run nutria supply curve is presented in Figure 4. This backward bending supply curve is generated by setting all environmental variables and the unemployment rate at recent (2004–2005) values. Under this set of

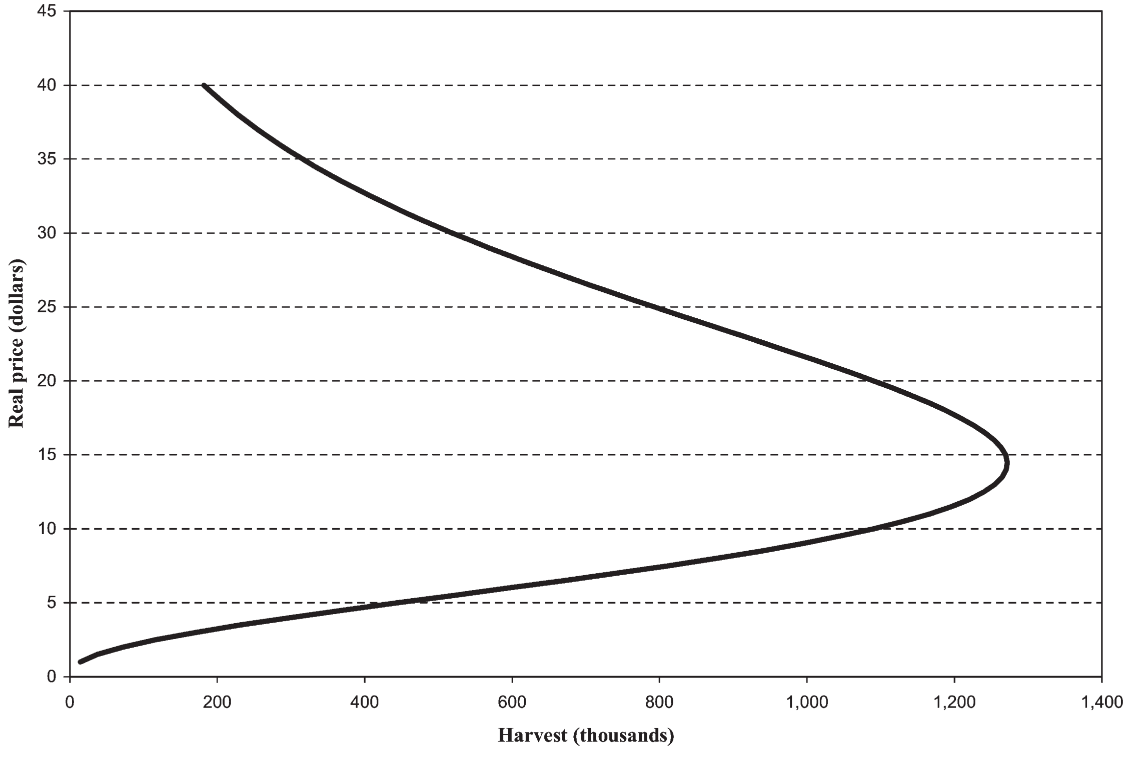

Figure 4. A Long-run Nutria Supply Curve (curve generated by setting all explanatory variables at their values in 2004–2005 season and varying the value of the deflated price)

Table 3. Predicted Nutria Harvests and Associated 95% Confidence Intervals at Various Bounty Levels

Bounty Level ($)	Lower 95% Confidence Limit	Predicted Harvest	Upper 95% Confidence Limit
4	171,054	287,524	458,215
5	234,535	391,579	619,848
6	318,270	531,383	841,152
8	475,868	802,151	1,281,975
10	600,185	1,024,970	1,659,552
12	678,761	1,178,625	1,940,385
14	709,071	1,260,203	2,123,463

conditions, nutria harvests will initially increase as the price (represented by the market price supplemented any bounty) increases until an MSY of 1.27 million animals is reached. After that, an increase in price will lead to a decrease in harvest.

Another application of the estimated supply model was to predict harvest quantities associated with different bounty levels, assuming all other variables were fixed at 2004 levels. Generally speaking, the bounty supplements the existing market price. Given that the $4.00 bounty was large relative to the existing market price, however, the bounty led to the undesired effect of discouraging trappers from undertaking the laborious task of skinning and readying the product for sale.[11] Predicted harvest associated with various bounties levels and the associated confidence intervals are presented in Table 3. As indicated, results suggest that an economic incentive of $4.00 per delivered tail may not be sufficient to achieve the stated harvesting goal of the program (400,000 nutria annually). Specifically, the predicted harvest at a $4.00 bounty is only 288 thousand animals, which is about 110 thousand animals less than the stated goal. In fact, the Louisiana Department of Wildlife and Fisheries recognized that the program was falling short of its goal and announced in September 2006 that the bounty would be increased to $5.00 per delivered tail for the 2006–2007 season. As indicated by the information in Table 3, this bounty is likely to achieve the program's goal.

Despite the apparent ability of the open-access model to accurately predict harvest and the effects of various bounties, discussion of one shortcoming of the model is warranted. As previously noted, increases (decreases) in industry costs (i.e., unemployment rate in this analysis) should, according to theory, result in an upward (downward) shift in the long-run yield curve with no change in the curve shape. Hence, MSY is not affected by the industry cost structure. While regression limitations preclude incorporation of this concept in applied analysis, results of our current analysis illustrate that changes in industry costs have an impact on long-run yield.

Conclusions

The study results indicated that Louisiana trappers respond strongly to price incentives and that a bounty, under various conditions, can be successful at encouraging trappers to increase harvesting for the purpose of controlling an invasive vertebrate species. Although there are alternative methods for managing the nutria population including chemical control (toxicants), induced infertility, and chemical repellents, the upfront costs required to successfully implement these methods and the concerns about their negative effects on other nontargeted species are major limiting factors (Genesis Laboratories, Inc. 2002). On the other hand, the bounty method can be cost effective and easy to manage since it requires a minimum of direct involvement by

[11] As an indication of this fact, the reported price received by trappers during the 2002–2004 period averaged just $4.29 per animal. For purposes of analysis, it is assumed that no market sales would occur at bounties in excess of $4.00.

state personnel. At the very least, the experience of Louisiana suggested that the costs and acceptability of alternative methods must be carefully weighed when constructing an invasive species control program. For example, the bounty program in Louisiana has apparently received little opposition due, in part, to the fact that the linkage of nutria population to wetland degradation has been well established and the benefits of a healthy wetland ecosystem were understood by the public.

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