Estimating the Supply Curve for Nutria Pelts from Coastal Louisiana and the Impacts Associated with Declining Prices

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Introduction

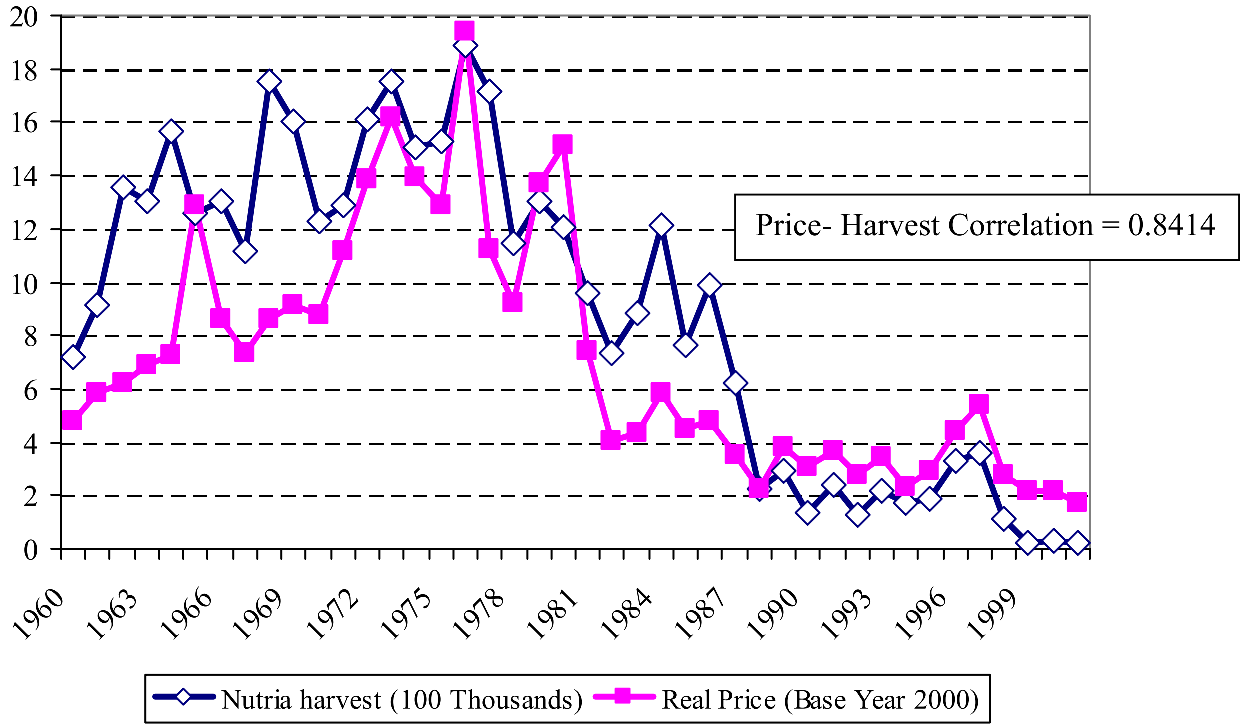
The nutria (*Myocastor coypus*), an invasive, semi-aquatic rodent native to South America, was introduced into Louisiana in the 1930's and 1940's in attempts to stimulate local fur farming and trapping economies. Well-adapted to Louisiana's coastal wetlands and with few natural predators, their populations expanded rapidly. By the late 1950's, the nutria population on the Louisiana coast was 20 million (Kinler, 1992).

Louisiana trappers began pursuing nutria as a source of fur income in the 1950's. In 1958, they were removed from the state's protected species list. By 1960, nutria harvests overtook muskrat harvests to become the leading furbearing species in the state. By the early 1960's, nutria populations were capable of supporting a commercial fur harvest exceeding 1 million animals.

Along with the growth of nutria as a fur resource came problems associated with their feeding habits. The nutria's high reproduction rate means that their numbers can expand relatively quickly, placing population pressures on the marsh ecosystems in which they live. Moreover, their appetite for marsh plants and their tendency to dig and feed on plant roots destroys plant biomass in quantities greater than the amount they consume directly (Kinler, Linscombe, and Ramsey, 1987; Kinler, 1992).

Since price was one of the main factors determining the quantity of nutria harvested (Figure 1), it was noted that when pelt prices were relatively high, the quantity of nutria trapped kept nutria populations and their effect on wetlands at "acceptable"

Figure 1. Louisiana Nutria Harvest and Price: 1960 - 2001



levels. However, when prices declined, the nutria harvest dropped allowing nutria populations to reach levels associated with undesirable amount of wetland damage.

Economic factors, price and the amount of trapping effort, appear to influence nutria populations and consequently wetland conservation. The Louisiana Department of Wildlife and Fisheries was aware of this when they implemented a bounty program offering $4.00 per nutria tail to induce more trappers to capture nutria and reduce the destructive pressure on the state's coastal marsh (Marx, Mouton, and Linsombe, 2004).

Nevertheless, the question remains: at what price is the harvest sufficient to reduce or prevent nutria-related wetland deterioration? This paper seeks to address this question by generating a nutria supply curve to examine the relationship between price and predicted harvest. The results of this supply curve can then be joined with a nutria-biomass-area biological simulation model to examine the changes in vegetated marsh area that result from changes in price and nutria harvests.

Conceptual Model

This paper estimates long-run nutria harvests in Louisiana as a function of economic parameters, namely pelt price and opportunity cost, and environmental parameters, temperature and alligator populations (Table 1). The model will generate a long-run supply curve for nutria pelts produced by independent producers (trappers) using a population dynamics model often used in fisheries models.

The nutria supply curve is expected to be backwards-bending in reflection of the possibility of harvests exceeding maximum sustainable yield at “high” prices. Backwards-bending supply curves may arise in open-access biological resources such as fishery stocks (Copes, 1970; Bell, 1978). Individual producers expend the quantity of effort where long-run harvest or revenue equals total costs (Figure 2). As price increases, the quantity of effort increases. Harvests increase with the increase in effort until they reach the population consistent with maximum sustainable yield. Further increases in effort will reduce population and decrease the sustainable quantity of harvest (Figure 3).

Table 1. Conceptual Model for Sustainable Supply Curve

Quantity of Nutria Harvested	= f(Price; Unemployment Rate; Alligator Populations; Winter Severity Index)
Parameter	**Expected Relationship**
Price	Quadratic (Backwards bending)
Unemployment Rate (Opportunity Cost)	Positive
Alligator Populations	Negative
Winter Severity Index	Positive/Negative

Figure 2. Hypothetical Long-Run Equilibrium Curve for the Louisiana Nutria Industry

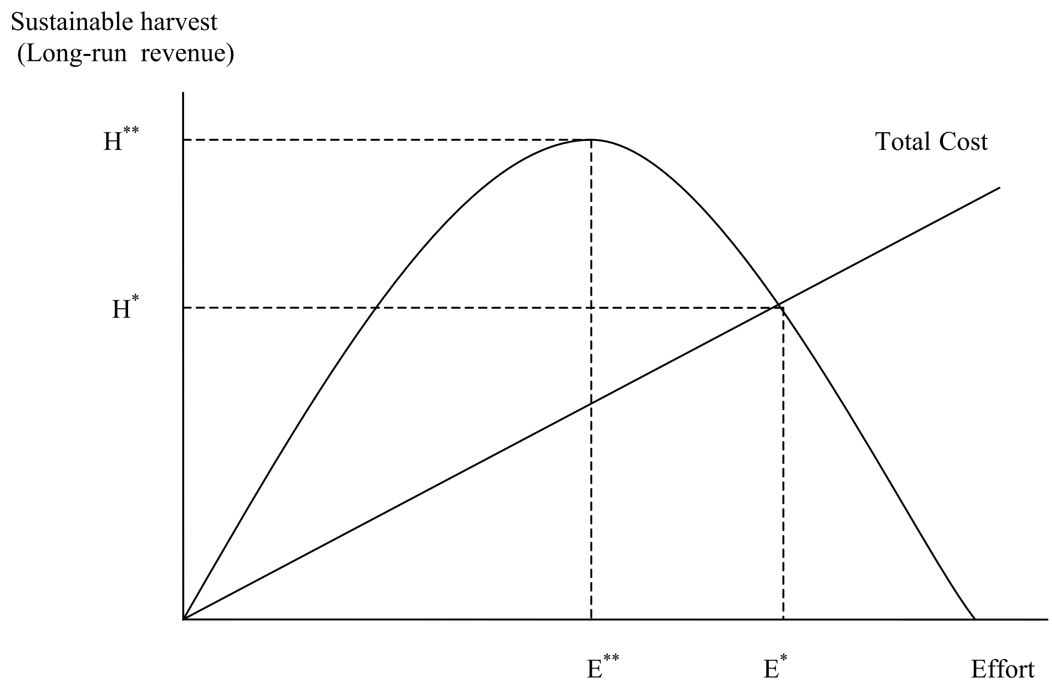
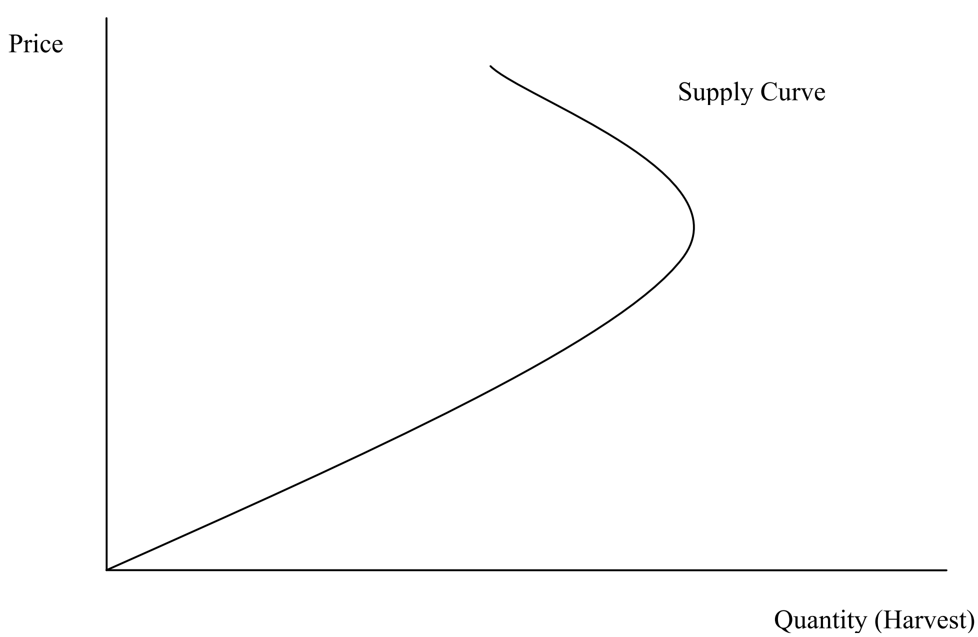


Figure 3. Hypothetical Long-Run Supply Curve for the Louisiana Nutria Industry



Harvests are expected to be negatively related to opportunity cost, the local unemployment rate. As the unemployment rate increases, the opportunity cost of the time spent trapping decreases resulting in an increase in the quantity of nutria pelts harvested.

Environmental conditions are seen as additional supply curve shifters. Because alligators have been identified as predators of nutria, especially in areas of high population density (Chabreck, 1987, Willner, *et al.*, 1982), a negative relationship is expected between alligator populations and nutria harvests.

There are competing hypotheses for the relationship between nutria harvests and freezing temperatures. Because episodes of extreme cold are reported to kill or injure nutria, it is possible to see a negative sign between the nutria harvests and the incidence of temperatures beneath the freezing point (32°F) in the current year or preceding year. Alternatively, the occasion of freezes (in all but the most extreme cases) may alter nutria behavior and wetland landscapes in such a way as to increase the quantity harvested per unit of trapper effort. In such a case, a positive sign between the quantity of nutria harvested and current and previous freeze may be possible.

Data sources

In order to estimate the bio-economics model of nutria, data were gathered on the following variables: catch (number of pelts), price per pelt, wetlands losses, unemployment rate in the coastal parishes, and winter temperature.

Harvest and price data.

This analysis uses Louisiana Department of Wildlife and Fisheries data for Louisiana's nutria production (1944 to 2002) obtained from fur dealers' annual reports to the Department detailing the number of pelts purchased from and prices paid to Louisiana trappers. Price data equal the average current per pelt price received by trappers in a given year. In order to adjust for inflation, the current price was deflated by the Bureau of Economic Analysis Implicit Price Deflator (base year = 2000).

Wetland acreage

Data on wetland losses in Louisiana were available from 1934 until the present. This data is not routinely collected on an annual basis. Annual estimates of wetland loss were extrapolated from periodic enumerations of wetland area according to a method described in Turner (1997).

Annual wetlands acreage was generated using 1968 wetlands acreage as a base year. Cumulative losses were added to the base year total for years prior to 1968 and subtracted from the 1968 total for subsequent years to derive annual estimates of coastal wetland acreage**.**

Winter Severity Index

The source of meteorological data used in the winter severity index is the New Orleans Audubon Weather Center of the National Oceanographic and Atmospheric Administration. Daily temperature measurements were used in a formula, similar to the one developed by Gosling (1981) to calculate the number of runs or spells of freezes each winter. Gosling's original formula is based on ice formation conditions and takes into consideration the fact that the effect of the number of runs will be cumulative through the winter; the run being the number of succeeding freezing days (defined as 24-hour period where the maximum temperature is less than or equal 5°C (41° F) and minimum temperature doesn't go above 0 °C (32° F)) during the winter.

$$CRS = \sum_{i=1}^{N} x_i^2$$

where χ is the length of the run or cold spell (in number of days) and i is the number of runs in the winter season (Gosling, 1981). This study adapts the same formula but defines a freezing day based solely upon a minimum temperature less to or equal to 32° F with no restriction on maximum temperature. Years identified in this research begin in December of the previous year to coincide with the trapping season data reported by Louisiana Department of Wildlife and Fisheries.

Unemployment rate

The annual unemployment rate (an opportunity cost measure) was calculated for the six Louisiana coastal parishes (Plaquemines, St. Bernard, Terrebonne, Vermilion, Calcasieu, and Cameron) from which most of nutria pelts were harvested. The yearly average unemployment rate is determined by adding the number of unemployed people for the six parishes and dividing the sum by the number of civil labor force for the six parishes. The data on unemployment by parishes is available from the U.S. Department of labor and the Louisiana Department of Labor for all years from 1970 until present as well as for 1960, 1962, and 1969. The state level unemployment rate was used for years for which parish unemployment data was unavailable. State-level unemployment rate data were sufficiently close to those from the six coastal parishes in those years for which data were available to support the substitution of state-level unemployment data for regional unemployment data in those years missing the desired statistics at the parish level.

Alligator Population Estimates

Alligator population estimates were provided by the Louisiana Department of Wildlife and Fisheries Fur and Refuge Division based on aerial nest counts. Annual population estimates were available from 1971 to the present. Populations for years between 1960 and 1970 was calculated based on a 13% survival rate (Kelly, 2004).

Model specification

The nutria supply model is developed by indirect simulation of the Fox model (1970), assuming a Gompertz growth function for the underlying population. This model does not predict zero harvest when the level of effort increases but allows harvest to approach zero asymptotically when the level of the effort continuously increases (Bell. 1978; Fox 1970) .

The anticipated nutria supply equation is:

$$Harvest\_he = P * \exp^{(\beta_0 + \beta_1 P + \beta_2 UNEMPLOYED + \beta_3 ALLIGATOR + \beta_4 FREEZE + Error)}$$

The dependent variable is harvest per hectare or the total nutria pelt harvest divided by the coastal wetland acreage for the state of Louisiana as estimated by the U.S. Geological Service.

The parameter P is the real price per pelt the trappers received, deflated by the Bureau of Economic Analysis' Implicit Price deflator (base year = 2000).

UNEMPLOYED is the standardized unemployment rate for six coastal parishes in Louisiana. The value for a given year represents the difference between that year's unemployment and the mean.

ALLIGATOR is the population of alligators per hectare. Populations are estimated provided by the Louisiana Department of Wildlife and Fisheries aerial survey were divided by the estimated coastal wetlands acreage in the state of Louisiana. FREEZE is the winter severity index measured using the modified version of Gosling formula.

Model Estimation

The nutria harvest sustainable supply equation was evaluated in SAS 9.0 using data from 1960 to 2001. Results are presented in table 2. All variables were significant.

The negative estimate on the PRICE variable (within the exponential expression) generates the hypothesized backwards-bending supply curve.

The positive sign on UNEMPLOYED is consistent with the hypothesis that harvests vary inversely with opportunity costs. An increase in the unemployment rate, being a decrease in the opportunity cost of trapping effort, would increase the harvests of nutria.

The negative sign on ALLIGATOR is consistent with the hypothesis that an increase in alligator populations and the associated rise in predation reduce nutria populations and consequently nutria harvests.

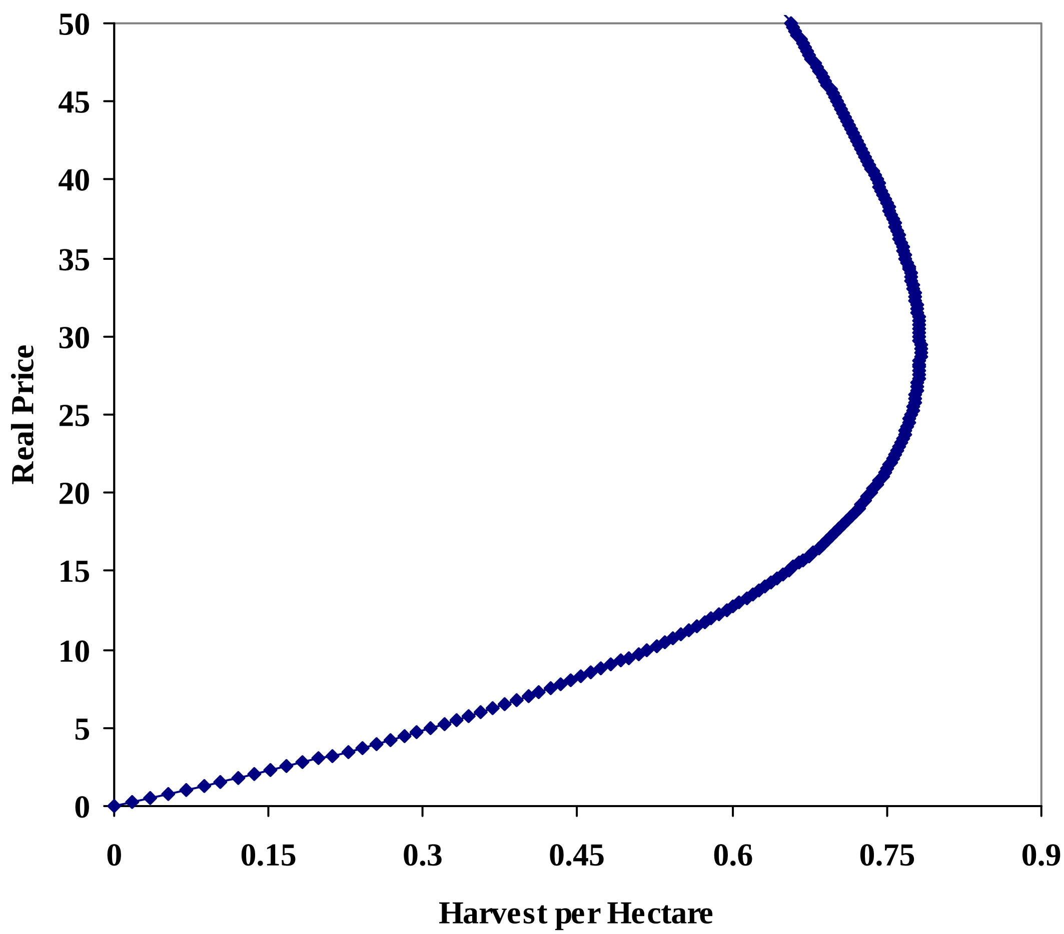
The positive sign on the winter severity index FREEZE supports the hypothesis that the incidence of freezes alters marsh conditions or nutria behavior in a manner that boosts harvests. Although this result is consistent with observations from trappers and others in the field, the exact reason for this phenomenon is uncertain.

A sustainable supply curve (Figure 3) was generated by varying pelt price while setting unemployment rate, alligator populations, and wetland acreage at the most current level and setting the winter severity index equal to its means. This curve is upwardsloping over the historic range of real pelt prices (minimum = $1.30; maximum = $19.43). The supply curve starts to bend backwards at a price of $29.18.

Table 2. Model Parameter Estimation

Harvest per Hectare = P*exp(β_0 + β_1*Price + β_2*Unemployed + β_3*Alligator + β_4*Freeze)				
Model Df = 5	Error Df = 36 R^2 = 0.8965	SSE = 0.5948 Adj. R^2 = 0.885	MSE = 0.0165 DW = 1.5055	
Parameter	**Estimate**	**Std. Error**	**t-Value**	**P > |t|**
Intercept	-1.94481	0.0955	-20.37	<0.0001
Price	-0.03426	0.00695	-4.93	<0.0001
Unemployed	0.160806	0.0416	3.86	0.0004
Alligator	-27.4361	6.0559	-4.53	<0.0001
Freeze	0.005622	0.00176	3.19	0.0030

Figure 3. Supply Curve for Nutria



Predicted Harvests

To test the effect of the $4.00 per tail bounty, the predicted nutria harvest under a bounty system was compared to harvest without a bounty. Without a bounty, the value of a nutria trapped is the per pelt price ($1.71 in 2002 and $1.38 in 2003). Under a bounty system, the value of a nutria is the sum of the value of the tails exchanged for the bounty plus the value of the fur sold to dealers divided by the total number of nutria trapped ($4.48 in 2002 and $4.38 in 2003).

For the 2002 conditions, this model predicts a per hectare harvest of 0.10165 nutria per hectare without the bounty and 0.24333 with the bounty, the equivalent of an aggregate statewide harvest of 137,884 and 330,068 respectively. The predicted harvests under 2003 conditions were 0.08619 nutria per hectare (116,913 statewide) without the bounty and 0.24852 nutria per hectare (337,108 statewide) with the bounty. The actual number of nutria harvested under the $4.00 per tail bounty system was 308,120 in 2002 and 332,596 in 2003.

When the bounty was set at $4.00 per tail, the Louisiana Department of Wildlife and Fisheries hoped for a harvest of 400,000 tails.(Marx, Jeffrey et al, 2004) Although the quantities predicted at the $4.00 level in the model and the quantities observed in the first two years of the bounty program are short of this goal, this model does not reject the hypothesis that a harvest of 400,000 nutria would be expected under a $4.00 bounty system.

This supply curve shows the expected harvest at a range of prices. The quantity of harvest will, in turn, have an effect on the wetland ecosystems in which the nutria are found. In the next section, this paper will explore the application of a biological simulation model that will use expected nutria harvests to examine the effect of pelt prices on nutria populations and associated wetland impact.

Biological Simulation Model

The effect of varying nutria harvests and wetland area loss is examined using a biological model developed by Carter, Foote, and Johnson-Randall, (1999) using the STELLA™ simulation program. This model links the nutria feeding behavior and wetlands losses and is composed of three linked components:1) the nutria population dynamic model; 2) the marsh plant biomass model; and 3) the marsh area model. The model main result can be summarized as follows:

1. As the number of nutria increases, the amount of biomass consumed increases. See Figure 4, Section A.

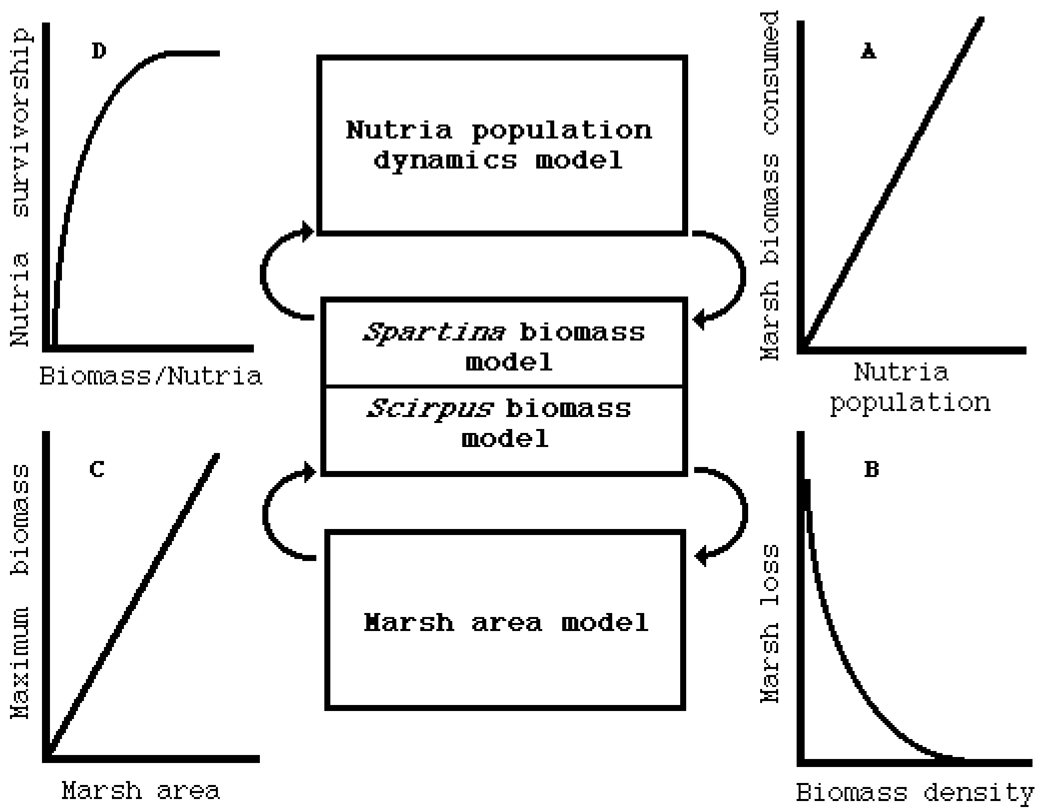
2. If the biomass density decreases below certain level, the critical density level, a part of the marsh area is lost; the lower the density, the bigger the size of the lost area (Section B of Figure 4).

3. As the area of the marsh decreases, the total biomass that the marsh can generate decreases, and the lesser is the number of nutria that can be supported (Sections C and D of Figure 4).

The model simulation ran with a time step of one week with a half-week interval between calculations with an initial population of nutria (40) on 20 hectares of marsh dominated by two common march grasses, *Spartina patens* and *Scripus americanus*. Model parameters, such as nutria sex ratios, pregnancy rates, gestation periods, and population dynamics, seasonal plant growth rates, nutria herbivory, and marsh density factors, were obtained by Carter, Foote, and Johnson-Randall, (1999) from the literature.

A standard nutria-biomass-area model was run for a 20 hectare plot with an emphasis on four key elements: (1) biomass (kilograms) of *Scripus americanus*; (2) biomass (kilograms) of *Spartina patens;* (3) vegetated marsh area in hectares; and (4) numbers of nutria. This standard model demonstrated a collapse in the vegetated marsh area within 104 weeks as nutria consumed the available biomass of *Spartina* and *Scirpus*. Nutria populations declined within 156 weeks, either perishing or moving to another location.

Figure 4. Conceptual Biological System Model



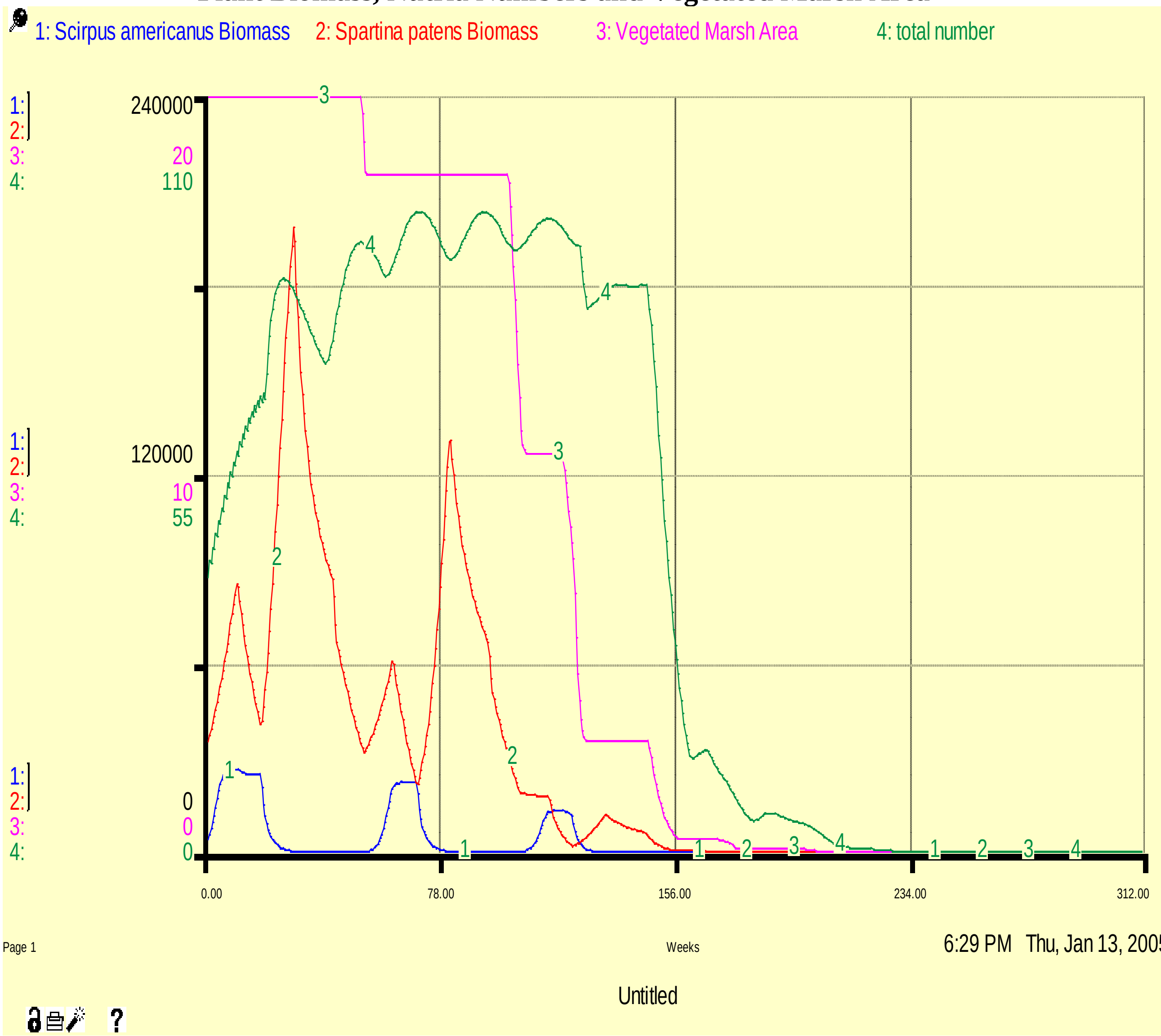
The original simulation model (Carter, Foote, and Johnson-Randall, 1999) included a harvest parameter: an annual harvest of 200 nutrias killed in the second week of the simulation model (early spring). In place of this original harvest value, this research inserted the quantities of harvest expected at various price levels. The seasonal per hectare harvest quantities generated from the supply curve were scaled to the 20-hectare plot used in the simulation model and distributed over a thirteen-week span that coincided with the historic Louisiana nutria trapping season, December through February.

The nutria-biomass-marsh model was run in STELLA version 8.1 over a 20-year range to demonstrate the simulated change in vegetated marsh area under the various price-harvest scenarios. This process began by calculating the expected nutria harvest from the supply equation in SAS 9.0 for various prices. As pelt prices and harvests rose, the negative impacts of nutria feeding habits were reduced. (An example of the graphical depiction of the changes in four parameters from a STELLA simulation can be seen in Figure 5.)

At the current market pelt price of $1.38 and a predicted seasonal harvest of 0.08619 nutria per hectare, the vegetated marsh area decreased to zero within three years according to this simulation (Figure 5). Under the bounty system, with an average value per nutria of $4.38 and a predicted seasonal harvest of 0.24852 nutria per hectare, the collapse of the vegetated marsh was postponed but nevertheless occurred within five years.

The collapse in vegetated marsh area in this simulation was avoided when the return to trappers increased by $4.00 to $8.38 per tail. At this incentive level, the predicted seasonal harvest rose to 0.41837 per hectare. At this level of harvest, the simulation reaches equilibrium with no change in vegetated marsh area.

Figure 5.
Example of Graph Generated in a STELLA Simulation Illustrating Changes in Plant Biomass, Nutria Numbers and Vegetated Marsh Area



Discussion

The impact of various price (or incentive) levels on nutria-related wetland loss can be examined by comparing the vegetated marsh extant at certain time intervals in this simulation. The simulation run here suggests that the nutria harvest expected at the current pelt market price is insufficient to prevent marsh loss. Vegetated area disappeared within three years.

The simulations also suggest that the harvests expected at the current $4.00 bounty level (0.24852 per hectare or 116,913 statewide) may slow the rate of nutria depredation but do not prevent the eventual marsh loss. Vegetated marsh area nevertheless collapses within 4.5 years.

Under this simulation, the goal of using trapper incentives to prevent the loss of wetlands from nutria depredation is accomplished only when the incentive is virtually doubled to $8.38. The corresponding predicted harvest, 0.41837 nutria per hectare, the equivalent of 567,503 statewide, is sufficient to preserve vegetated marsh area at a constant level.

These simulations, though illustrative, must be interpreted with some caution. For one, they are only computer-generated models of a complex natural system that may accurately reflect the ecosystem they represent. Many of the parameters used to construct the nutria-biomass-area model were imprecise or developed from sources outside Louisiana, possibly impairing the accuracy of the simulation (Carter, 2004).

In addition, the simulation model was constructed for only one type of ecosystem on which nutria are found, an intermediate brackish marsh. Attempts to reconfigure the model for other types of nutria habitat were not accomplished, largely due to a lack of data.

Furthermore, these simulations were performed for a small area of 20 hectares. It is difficult to interpolate the results from this hypothetical plot to a larger scale. The 20-hectare plots used in the simulation are enclosed with no migration of nutria into or out of the area as the condition of the wetlands changes. If nutria emigrate from an area before the complete elimination of vegetation, the impact across a broader range of wetlands may differ from that estimated in the simulation experiment.

The relationship between nutria populations and wetland loss is a matter of continuing study. Currently, enhanced versions of the nutria-biomass-area model are being constructed in various system simulation models (Carter, 2004; Delozier, 2004). As these models improve the understanding of the effect of nutria depredations on marsh deterioration, the economic-ecology interface will be improved.

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