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DEVELOPMENT OF A MODEL TO ASSESS RODENT CONTROL IN SWINE FACILITIES

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Abstract: At the request, and with the support, of the National Pork Producers Council we are conducting a comprehensive economic analysis of rodent control in swine production facilities. The authors represent an interdisciplinary working group that has been assembled to identify all necessary input variables and values associated with rodent damage and control. The working group consists of specialists in swine production, facilities management, agricultural economics, swine health, rodent control, the pest management industry, systems modeling, and distance education. We incorporated data from the scientific literature and personal experience into an interactive STELLA systems model. The model generates benefit-cost analyses and predicts outcomes of various levels of rodent control. Our simulations suggested that rodent damage and rodent control costs were minimized when US$350/month was spent on control. Further, simulations showed that net costs of rodent damage and control could be optimized at US$0. Eventually, the decision-assisting model will be made available to swine producers through Extension Agents and the Internet.

Key words: benefit, cost, damage, economics, house mouse, *Mus musculus,* rodent control, rodents, STELLA, swine

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Historically, little effort has been expended on the economic evaluation of vertebrate pest control and management (Dyer and Ward 1977, Caughley 1980, Dahlsten 1986, Dolbeer 1988). Researchers have placed more emphasis on determining statistical significance of experiments than on evaluating economic significance (Dillon 1977). The economics of rodent control in the food industry have not been evaluated closely, though it is assumed that the benefits of controlling rodent populations exceed the costs. Efforts to control rodents implicitly involve the expenditure of resources and are often very costly. The hope is that the costs are exceeded by the benefits that result from the control. To more fully understand the role rodents play in swine production systems, an economic evaluation of the damage caused and the costs of control is necessary.

In the Nebraska pork industry alone, house mice *(Mus musculus)* and Norway rats *(Rattus norvegicus)* cause an estimated annual loss of US$6.35 million in structural damage (Johnson and Timm 1987). In addition, the value of livestock feed consumed by rodents was estimated at US$0.75 million (Johnson and Timm 1987). The cost of rodent damage has increased in recent years as the use of insulated confinement structures has become more prevalent. House mice, in particular, can be very destructive, damaging all types of building insulation (Timm and Fisher 1986, Hygnstrom 1995). Further, mice and rats are known to serve as reservoirs and vectors of swine diseases, including: swine dysentery, encephalomyocarditis, swine erysipelas, trichinosis, and pseudorabies (Timm et al. 1996).

Effective control of rodents requires an integrated pest management (IPM) approach that involves sanitation, population reduction, and rodent-resistant construction (Hygnstrom and VerCauteren 1995). Integrated approaches to rodent control are effective and recommended (Corrigan et al. 1992, Timm et al. 1996), but little is known about the overall cost-effectiveness of various methods of rodent control.

Benefit-cost analysis is a generic term that encompasses a broad range of evaluation procedures to estimate the monetary gains and losses associated with a particular level of activity (Sassone and Schaffer 1978). Costs refer to the increase in something undesirable or lost opportunities to benefit (McAllister 1980). Benefits refer to a gain in something desirable or reduction in something undesirable (Hone 1994). When benefits exceed costs, the activity will be economically profitable. Though benefit-cost analyses are good criteria for making pest control decisions, there are real and practical difficulties in accurately conducting such analyses (Cherrett et al. 1971). In a dynamic system, like a swine production facility, determining the inputs required to obtain accurate benefit and cost figures is quite difficult and challenging.

Though complex, the economic modeling of systems is a worthwhile exercise. Richmond (1993) and Forrester (1994) stated that system dynamics and systems thinking aids in the comprehension and conceptualization of the varying and interacting components that function within a system. System-dynamics modeling is an interactive activity that allows the user to learn through simulation. Simulations (running the model several times with different input values), then, allow for the fast and efficient generation and testing of hypotheses and scenarios (Risenhoover et al. 1997). A good

Table 1. List of variables considered in a global model of rodent damage in swine facilities.

Biology	Damage	Monitoring	Control Strategies
birth	energy loss	trapping	sanitation
death	structural	track patches	facility maintenance
emigration	foundation	rodenticide consump.	toxicants
immigration	curtain	infra-red video	trapping
	insulation	visual inspection	rodent-resistant construct.
	ventilation	census blocks	
	heat loss		
	air/humidity		
	wiring		
	gnawing		
	stray voltage		
	corrosion		
	fire		
	plumbing		
	equipment		
	scales		
	feed bins		
	vehicles		
	disease		
	animal loss		
	veterinary expense		
	feed		
	consumption		
	contamination		

model will help users make informed decisions regarding the IPM strategies they are considering for controlling rodents in their facilities.

The overall goal of the model is to: 1) showcase the variables and their interactions that influence rodent management in swine facilities, 2) identify strategies to reduce damage and optimize expenditures, and 3) predict the response of rodent populations to control. The specific objective of this portion of the overall effort is to use a parsimonious model to elucidate economic trends associated with varied rodent population and control efforts.

MODEL DEVELOPMENT

Our IPM model of rodent populations and control in swine facilities is the product of the varied experiences of the individual co-authors and an exhaustive literature search (i.e., Agricola, Agris, Biological & Agricultural Index, Biosis, Dissertation Abstracts, Elsevier Biobase, Enviroline, General Sci, Life Science Collection, Mantis, SciSearch). A comprehensive list of variables related to rodents that may impact swine production was derived from our discussions and the literature (Table 1).

The model was constructed with STELLA 6.0 simulation software (High Performance Systems, Hanover, New Hampshire, USA). It is structured around a calendar year and we have set dt = 0.25, so a round of calculations is performed every week. Minimum system requirements to run the model include Windows 3.1, a 486 processor, 8MB Ram, and 16MB of hard disk space. Besides STELLA modeling software, QuikTimeTM software is also required. Though the model was created on an IBM-based personal computer, it can be

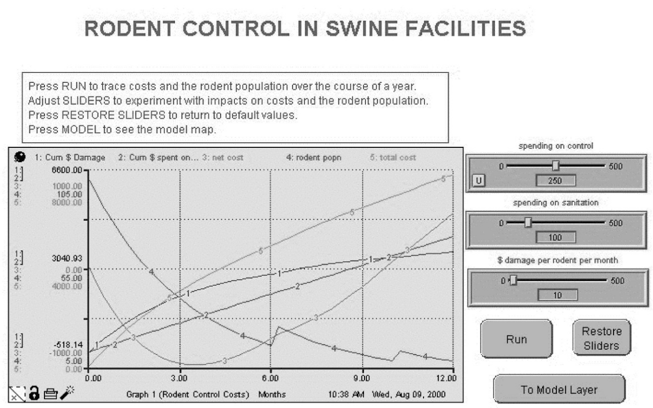

Fig. 1. The controls layer of the model, on this layer model users can vary input values and run the model to see how their changes influence the values depicted on the graph.

Table 2. Default values for variables in the rodent control in swine facilities model, US$.

Variable	Default value
Initial rodent population	$100
Toxicant and trapping level/month	$140
Sanitation level/month	$100
Damage/rodent/month	$10

executed on a Macintosh system. See the STELLA FAQ for instructions on exporting the model to a Macintosh system.

The model consists of 3 layers: an interactive controls layer, a model diagram layer, and an equations layer. The purpose of the layering is to manage complexity, for both producers and consumers of the model (STELLA Technical Documentation 1997). In the controls layer, model users can run simulations under the varying scenarios that they select (Fig. 1). Default values in the model are assumed mean monthly estimates of the initial rodent population size, control costs, and the amount of damage/rodent/month (Table 2). These values may be modified and our confidence in them may increase as the model evolves. Though currently stated as a constant, the amount of damage/rodent/month may eventually be related to probabilities. The higher the rodent population, the greater the chance of an individual causing substantial damage to the facility (i.e., electrical fire, diseases in swine). The cumulative costs of rodent damage and control are plotted, as is the net cost (cumulative cost of control – cumulative cost of damage). We also plot the number of rodents in the population, relative to control effort. Further, the model plots the total cost (cumulative cost of damage + cumulative cost of control), which is the most telling to the model user.

The second layer of the model is called the diagram layer. It shows the layout of the model variables in the form of stocks (rodent population, cumulative dollars spent on control, and cumulative dollars of

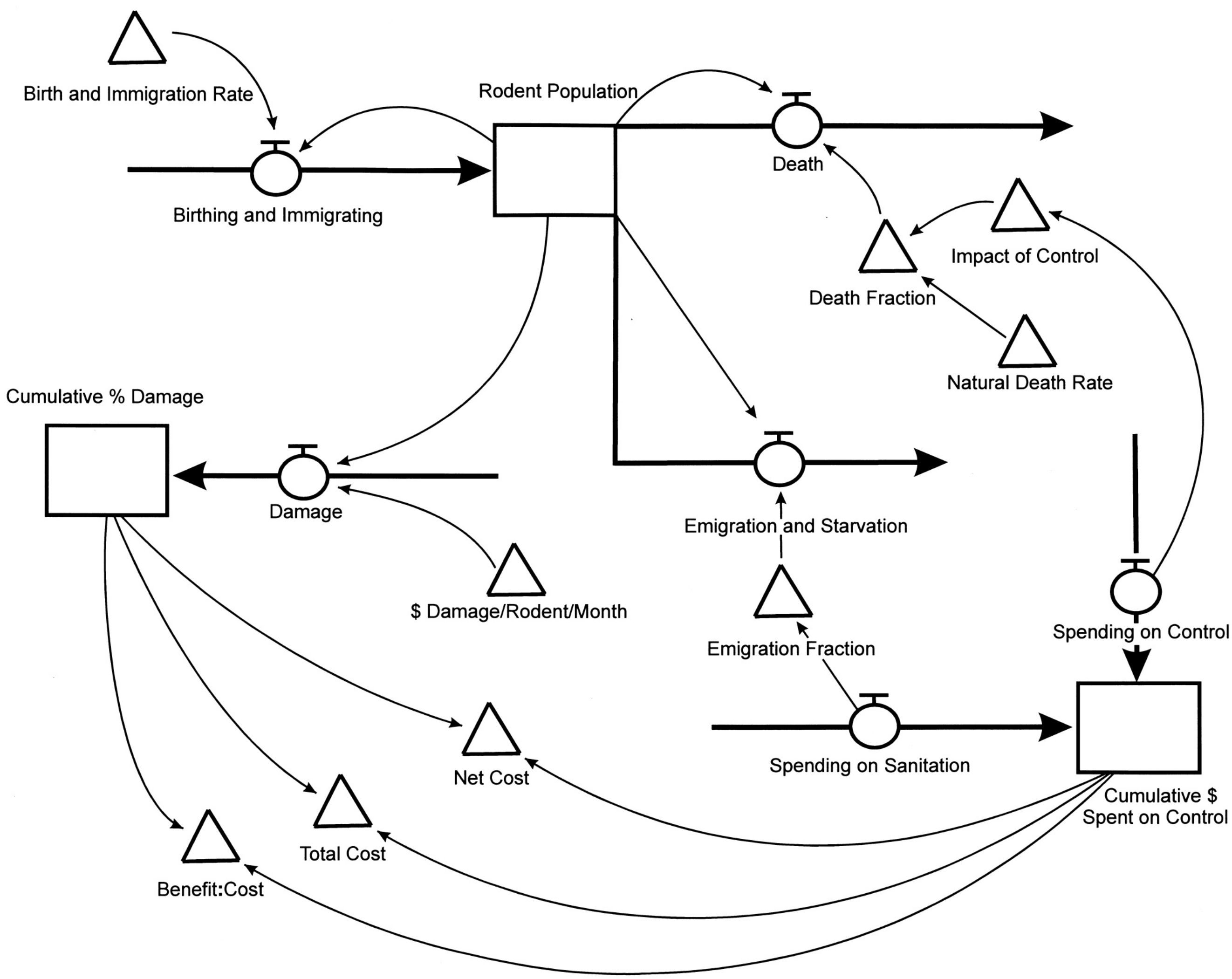

Fig. 2. The diagram layer of the model, showing the layout of the variables and their relationships to other variables.

damage), flows (e.g., death, damage, spending on sanitation), converters (e.g., damage, death fraction, total cost), and connectors (the single-lined arrows) (Fig. 2). The diagram layer gives the user a detailed representation of the relevant processes.

The third layer lists the equations depicted in the second layer (Table 3), allowing the interested user to more completely understand the functioning of the model and the system. If desired, the advanced user could modify aspects of the model in the second or third layer.

The model allows the user to input the site-specific initial population of rodents, the monthly cost of direct control (toxicants and trapping), and the monthly cost of indirect control (sanitation). The model assumes, based on population growth curves, that the more spent each month on toxicants, trapping, and sanitation the higher the level of rodent mortality and emigration. The better the initial values provided by the user the better the confidence in the model output. Caution must be exercised, however, when using economic models because inaccuracies in parameter values, multiplicative error, and violated assumptions can lead to spurious results (Maynard-Smith 1974).

We began by modeling those variables that we assumed to be most influential to the system. Our goal was to model as many variables as necessary to maximize the model's ability to predict benefits and costs while minimizing the number of variables included. More variables may be added as the model evolves. Examples of such variables include: rodent population levels, rodent impacts (e.g., structural, feed consumption, disease), control methods (e.g., sanitation, rodent-resistant construction, toxicants), facility type, and levels of control (e.g., minimum maintenance, corrective applications, contracted eradication).

Table 3. The equations layer of the model, lists the equations depicted in the diagram layer.

Equations
Cum. dollars damage(t) = cum. dollars damage(t ? dt) + (damage) * dt
Initial cum. dollars damage = 1
Damage = rodent popn.*dollars damage/rodent/month
Cum. dollars spent on control(t) = cum. dollars spent on control(t ? dt) + (spending on sanitation + spending on control) * dt
Initial cum. dollars spent on control = 1
Spending on sanitation = 100
Spending on control = 110
Rodent popn.(t) = rodent popn.(t ? dt) + (birthing & immigrating ? death ? emigration & starvation) * dt
Initial rodent popn. = 100
Birthing & immigrating = birth & immigration rate*rodent popn.
Death = rodent popn.*death fraction
Emigration & starvation = rodent popn.*emigration fraction
Dollars damage/rodent/month = 10
Benefit:cost = cum. dollars damage/cum. dollars spent on control
Birth and immigration rate = .3+PULSE(.7,6,4)
Death fraction = natural death rate+impact of control df
Natural death rate = .1
Net cost = cum. dollars spent on control-cum. dollars damage
Total cost = cum. dollars damage+cum dollars spent on control
Emigration fraction = GRAPH(spending on sanitation)
(0.00, 0.035), (50.0, 0.04), (100, 0.06), (150, 0.09), (200, 0.11), (250, 0.2), (300, 0.36), (350, 0.445), (400, 0.475), (450, 0.51), (500, 0.515)
Impact of control df = GRAPH(spending on control)
(0.00, 0.03), (50.0, 0.135), (100, 0.215), (150, 0.285), (200, 0.365), (250, 0.44), (300, 0.52), (350, 0.61), (400, 0.7), (450, 0.82), (500, 0.895)

Table 4. The level of monthly control through toxicants and trapping, and the associated annual costs, necessary to achieve rodent populations of 0, 10, 50, 100, 500, and 1,000 individuals. The initial rodent population was 100 individuals, sanitation level was US$100/month, and each rodent was assumed to do US$10 damage/month.

	Population size after 1 year					
Cost	0	10	50	100	500	1000
Toxicant and trapping level	$350+a	$240	$150	$110	$30	$0
Cum. cost of control	$5,406	$4,081	$3,001	$2,521	$1,561	$1,201
Cum. cost of damage	$2,199	$3,840	$7,298	$10,073	$25,501	$41,534
Net cost	$3,087	$241	-$4,297	-$7,552	-$23,940	-$40,333
Total cost	$7,605+[a]	$7,921	$10,299	$12,286	$25,790	$42,735

[a] Toxicant and trapping levels >$350/month would also have brought the population to 0, but would have increased the total cost.

MODEL SIMULATION

We ran several simulations of the model to determine the level of monthly control necessary to drive the rodent population to 0, 10, 50, 100, 500, and 1000 individuals in one year (Table 4). For these simulations, the initial rodent population was 100 individuals, the level of sanitation remained constant at US$100 of sanitation effort per month, and individual rodents were assumed to do US$10 worth of damage each month. Results of simulations indicated that total costs could be minimized by spending US$350/month on control. Less than US$350/month spent on control led to increased total costs due to increased levels of rodent damage. More than US$350/month spent on control served to decrease the rodent population more rapidly, but also increased total costs because once the population was lowered substantially, little damage was done, though eradication effort was high.

Relationships between the control costs and damage costs can be compared throughout the year. For example, in Fig. 1, the initial rodent population is 100, US$250/month is spent on toxicants and trapping, US$100/month is spent on sanitation, and each rodent is assumed to do US$10 damage/month. By tracing the rodent population, the user can see that this level of control serves to rapidly reduce the population, except for a substantial birth pulse in June (although young are added to the population each month at a rate of 30%, we added 100% in June for illustrative purposes) and an immigration pulse (of 100%) in October. During March-April the cost of damage exceeds that being spent on control and net cost, in the form of excessive rodent damage, is maximized. As the year goes on, the control effort reduces the population and by September, the economic loss to damage equals that being spent on control. The net cost, therefore, is optimized at US$0 at this point. As the year continues, more is being spent on control than is necessary, functioning to drive up the net cost. In this scenario, the total cost to the producer at the end of the year due to rodent damage and control costs was US$7,832.

CONCLUSIONS AND FUTURE DIRECTIONS

The interactive system-dynamics model we are developing will be made available to swine producers through Extension Agents and the Internet. Our comprehensive economic evaluation of rodent control in swine production facilities is needed to increase producer awareness and efficiency. Producers will be able to input information from their own facilities and generate economic analyses that will assist them in selecting the most cost-effective rodent control practices. The model will provide swine producers a greater awareness of potential rodent damage, so that such damage can be prevented or corrected before it exceeds economic thresholds. The success of this effort will be quantified in terms of the percentage of swine producers who evaluate their production units in terms of potential or ongoing rodent damage and subsequently take appropriate steps to prevent or control rodent damage. The information provided by the model will be used by industry professionals such as research scientists; livestock building engineers, contractors, and designers; veterinarians; and structural pest control operators. The model will also help researchers identify gaps in current knowledge regarding the impacts of rodents and the benefits and costs of rodent control. Such information will be useful in identifying future research priorities.

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