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ORAL RABIES VACCINATION: REDUCING ECONOMIC UNCERTAINTY VIA RESPONSE SURFACE ANALYSIS

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Abstract: Economic uncertainty surrounds the distribution of Raboral V-RG7 as an oral rabies vaccine (ORV) bait for the containment or elimination of raccoon-variant rabies in the United States. This paper describes a costs-savings model of ORV. It also describes Excel XP7 code that was prepared to compute potential net savings (NS) and benefit-cost ratios (BCRs) associated with Raboral V-RG7 bait distributions. Currently, baits and bait distributions are relatively expensive; individual baits are produced at a cost of \$1.27 for federal use and typically dispensed at >75 baits/km^2. Distribution is estimated at \$8.62/km^2, \$15.80/km^2, and \$33.30/km^2 for fixed-winged (FW), ground (Gnd), and rotary-winged (RW) applications, respectively. Although many assumptions are required, iterative runs of the code allow plotting NS and BCR response surfaces for diverse scenarios based on 6 ORV variables: area (km^2), bait-price (US\$/vaccine bait), bait-density (#/km^2), application frequency (n), mode-of-delivery [\$US for % fixed-winged (FW), % rotary-winged (RW), and % ground-dispensed (Gnd)], and effectiveness (% seropositive titer conversion). Using a raccoon-rabies-epizootic-containment scenario for parts of Pennsylvania and a modest epizootic cost estimate of \$40 million, the greatest NS (\$6.4 to 38.4 million) and BCR (2.85 to 25.76) indices occurred for a one-time bait distribution involving FW aircraft over a fourth of the state with a \$0.90/bait price. As expected, greater reliance on the more expensive RW and Gnd modes of bait distribution compared to FW aircraft, coupled with higher bait prices and higher bait densities, decreased NS and BCR indices. The utility of the approach to economic forecasting and decision making of ORV effects are discussed.

Key words: direct costs, economics, oral vaccination, *Procyon lotor*, rabies, raccoon, uncertainty

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INTRODUCTION

Oral wildlife vaccines have been effective in limiting or eliminating coyote (*Canis latrans*) and red fox (*Vulpes vulpes*) transmitted rabies in areas of North America (Farneyhough et al. 1998; MacInnes et al. 2001). Currently, raccoon variant rabies is enzootic, or likely to become enzootic, in 19 Eastern states (i.e., Alabama, Connecticut, Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, Tennessee, Vermont, Virginia, and West Virginia) and the District of Columbia (CDC 2001). Fish-meal polymer baits exist for effectively delivering oral vaccines to raccoons (Olson et al. 2000); These are Raboral V-RG7 baits (Merial Limited, Athens, Georgia, USA). An ORV program has been initiated to vaccinate wild raccoons along the Appalachian Ridge to stop the westward spread of this disease (Foroutan et al. 2002, Slate et al. 2002, USDA 2001).

Economic uncertainty surrounds the use of these baits. This is due in part to the difficulty in determining regional costs of the disease and in assessing potential savings likely to result from an ORV program. Although some data have been published about post-exposure human prophylaxis (PEP) and bait-distribution costs (see Foroutan et al. 2002, Kemere et al. 2002, Kreindel et al. 1998, Meltzer and Rupprecht 1998, Uaaa et al. 1992), these studies lack systematic projections of the relative costs and savings likely with ORV.

Recently, Sterner (2002), Sterner and Lorimer (2001), and Sterner and Tope (2002) described an *a priori* approach to examining the potential benefits and costs of wildlife-damage-management activities. Spreadsheet software (Lotus7 1-2-37, 9.5 software, Lotus Development, Cambridge, MA) was used to compute iterative net savings (NSs) and benefit-cost ratios (BCRs) linked with the use of several wildlife management products (e.g., a rodenticide for vole control in alfalfa, a commercial repellent for nuisance goose management at golf courses). Fixed scenarios were used to illustrate the possible losses and prevention of losses likely from the use of these products. Multiple runs of the programs, with 1-factor-changed-at-a-time (e.g., product price, application rate, persistence, area treated, amount of loss expected), allowed plotting numerous NS and BCR outputs for a range of inputsBthe response surfaces of these indices. The approach afforded useful simulations of potential benefits and costs linked with the products.

Here, we present a cost-savings model for using ORV to contain raccoon-variant rabies. We then describe Excel XP7 code (Microsoft7 Corp., Richmond, Washington, USA) that was prepared to estimate NS and BCR indices associated with key factors involved in Raboral V-RG7 bait distribution; a hypothetical ORV scenario is used to illustrate use of the code.

COST-SAVINGS MODEL

Our model attributes the impact of animal rabies in the U. S. economy to diverse veterinary, medical, legal, and insurance costs. The potential saving any of these costs is viewed as the benefit of ORV.

Nature of Costs-Savings

Economists identify 3 categories of costs and benefits: direct, indirect, and induced (see Field 2001). Direct costs involve actual monetary expenses attributable to occurrence of rabies (e.g., pet vaccination biologics, replacement price of a companion animal, ORV bait, rabid animal quarantine, pre- and post-exposure medical prophylaxis, life insurance claim). The term indirect refers to those tangential costs or savings that are rabies-related expenses but which are incidental to direct costs (e.g., lost work by patients due to side effects of prophylaxis, travel to medical facilities). Induced costs also refer to a class of tangential costs or savings that are due strictly to implementation of ORV (e.g., labor costs to trap raccoons for rabies surveillance, serum tests on raccoons to monitor vaccine effectiveness).

Nature of Rabies and ORV

Multiple variants of the rabies virus occur in the U. S.: bat, canine coyote, arctic fox, red fox, raccoon, and skunk (Childs 2002). These variants currently occupy prescribed geographical regions, but variants ascribed to different mammals occur simultaneously (overlap) in certain regions (Childs 2002). Any mammal can contract rabies from a bite by an animal having these variants; thus, it=s possible to have a rabid raccoon occur in California even though the raccoon variant virus has not been identified there (e.g., contract rabies from a bat). While ORV baits exist for coyote, fox, and raccoons, oral vaccines for bat or skunk variant rabies have yet to be developed (Johnston and Tinline 2002).

Equations

The following equations define our model:

C = [CAV + LV + CAR + LR + Q + PreEP + PEP + PH + HD],

where C is the additive cost of a raccoon variant rabies epizootic ($US). If ORV is effective, these costs become potential savings (S). Epizootic C is attributed to 9 main variables:

CAVBCompanion animal vaccinations (n A $US/vaccination),

LVB livestock vaccinations (n A $US/vaccination),

CARBcompanion animal replacements (n A $US/animal for rabies-caused deaths),

LRBlivestock replacements (n A $US/head for rabies-caused deaths),

QBquarantine of suspected rabid animals (n A $US/event),

PreEPBhuman pre-exposure-prophylaxis (n A $US/vaccination),

PEPBhuman post-exposure-prophylaxis (n A $US/treatments),

PHBpublic health charges (n A $US/event for case investigations and laboratory tests),

HDBinsured human death claims (n A $/death). [Note.BTo date, one human death has been attributed to raccoon rabies.]

Potential net savings (NS) afforded by raccoon variant ORV are viewed as C less the ORV costs and any accident-related charges (ACC):

NS = (C A E) - (ORV + ACC).

where NS is total net savings, C is defined above, E is the likely effectiveness benefit (sero-positive conversion), ORV is the cost of the baiting program and is dependent upon: area (km^2), bait cost ($US/bait), bait density (baits/km^2), mode-of-bait distribution [($US fixed-wing /rotary-wing /ground (%FW/%RW/%Gnd)], number of baitings (n), and ACC is baiting-related accidents/injuries (n A $US/medical + $US/liability settlement). [Note.BBait equipment is considered a pro-rated $US charge embedded with mode-of-bait distribution; currently such equipment sells for about $3,500/unit and is computerized to dispense baits at prescribed rates on GIS-based azimuths; C. MacInnes, personal communication, 2003). Obviously, effectiveness is difficult to derive; it assumes that returns on invested ORV monies are related to the proportion of raccoons successfully vaccinated as well as overall suppression of the disease and curtailment of future costs. These are not necessarily equivalent or directly related; it is unknown what portion of a population of raccoons need to be vaccinated within an area to successfully stop transmission or eliminate the disease. Still, for current purposes, we have elected to model this factor based upon the simple percentage of raccoons hypothetically vaccinated (i.e., 25, 50, 75, or 100%) --

hypothetical effectiveness of preventing rabies-incurred costs. Additionally, ACC is considered to be zero ($0.00). To date, only 1 accidental dosing with the Raboral V-RG7 bait has occurred; an Ohio woman was dosed while trying to retrieve a bait from her dog. This incident was resolved in court; medical assistance was waived by the plaintiff and no liability was determined (R. Hale, personal communication, 2003).

Finally, a BCR is derived using the potential savings (S) in costs of the epizootic, or the expected C:

$$BCR = (C A E)) (ORV + ACC),$$

where C, E, ORV, and ACC are defined as above. This ratio reflects potential future savings in raccoon epizootic expenses due to Raboral V-RG7 bait distribution. It is a relative value, rendering area (km^2) irrelevant. A ratio of 1.0 refers to equality of ORV expenses and potential S; values <1.0 or >1.0 indicate that benefits are likely to be smaller or larger than ORV outlays, respectively.

ESTIMATING ECONOMIC EFFECTS OF ORV

Excel XP7 code was prepared to compute and graph BCR and NS indices associated with ORV bait distributions. As implied in the model, 6 parameters are viewed to determine the potential costs of Raboral V-RG7 bait distributions: (1) area of bait application (km^2), (2) bait price ($/bait), (3) bait density (baits/km^2), (4) bait application frequency (n), (5) mode of bait distribution (km^2 FW, RW, and Gnd), and (6) effectiveness (% sero-positive conversion of wild raccoons). Of course, the probable cost (C) of the epizootic (or potential S) must be input. Induced costs of surveillance and testing raccoons in ORV areas were not programmed. Iterative, 1-variable-changed-at-a-time runs of this code allowed plots and descriptions of the economic response surfaces that would be attributed to manipulations of specific variables substituted for the parameters.

Excel XP7 Code

Figure 1 presents the Excel XP7 output of potential NS and BCR indices. Detailed code for computing several cells of the spreadsheet is given in the caption; formulas for remaining cells of the matrix are readily derived by substitution.

As shown, input descriptors are listed in Cells A2-A7 of the sheet; these request information for area (km^2), FW (%), RW (%), Gnd (%) application, rabies cost ($US), and number of baitings (n). Actual inputs for these variables are entered in Cells B2-B7, respectively. Formulas for computing BCRs involving 5 designated bait prices [i.e., $0.90, $1.10, $1.30, $1.50, and $1.70; Column D (Cells D10-13, D15-18, D20-23, D25-28, and D30-33, respectively)] combined with each of 4 bait densities [i.e., 50, 75, 100, and 125 baits/km^2; Column E (Cells E10-13, E15-18, E20-23, E25-28, and E30-33, respectively)] and each of 4 sero-positive effectiveness variables [i.e., 25% in Column F (Cells F10-13, F15-18, F20-23, F25-28, and F30-33, respectively); 50% in Column G (Cells G10-13, G15-18, G20-23, G25-28, and G30-33, respectively); 75% in Column H (Cells H0-13, H15-18, H20-23, H25-28, and H30-33, respectively); and 100% in Column I (Cells I10-13, I15-18, I20-23, I25-28, and I30-33, respectively)] are programmed into the intersecting cells of the code. A similar matrix of NS values for these same inputs for

Figure 1. Schematic view of Excel XP7 output used to perform net savings and benefit-cost ratio estimates. Selected cell formulas are:

F10=($B$6*$F$9)/((($D$10*E10*$B$2)+$B$2*($B$3*8.5+$B$4*33.3+$B$5*15.8))*$B$7),
I33=($B$6*$I$9)/((($D$30*E33*$B$2)+$B$2*($B$3*8.5+$B$4*33.3+$B$5*15.8))*$B$7),
M10=($B$6*$M$9)-((($K$10*L10*$B$2)+$B$2*($B$3*8.5+$B$4*33.3+$B$5*15.8))*$B$7),
P3 =($B$6*$P$9)-((($D$30*L33*$B$2)+$B$2*($B$3*8.5+$B$4*33.3+$B$5*15.8))*$B$7).

A	B	C*	D	E	F	G	H	I	J	K	L	M	N	O	P
		1													
Area sq. km	29021	2													
%FW	100%	3													
%RW	0%	4													
%ATV	0%	5													
Epidemic cost	$40,000,000	6	Benefit-Cost		Ratios					Net Savings					
Baitings	1	7													
		8	Cost/ Bait	Bait Density	Sero+ Conversion Rates					Cost/ Bait	Bait Density	Sero+ Conversion Rates			
		9			25%	50%	75%	100%				25%	50%	75%	100%
		10	$0.90	50	6.44	12.88	19.32	25.76		$0.90	50	$8,447,377	$18,447,377	$28,447,377	$38,447,377
		11		75	4.53	9.07	13.60	18.14			75	$7,794,404	$17,794,404	$27,794,404	$37,794,404
		12		100	3.50	7.00	10.49	13.99			100	$7,141,432	$17,141,432	$27,141,432	$37,141,432
		13		125	2.85	5.70	8.54	11.39			125	$6,488,459	$16,488,459	$26,488,459	$36,488,459
		14													
		15	$1.10	50	5.43	10.85	16.28	21.71		$1.10	50	$8,157,167	$18,157,167	$28,157,167	$38,157,167
		16		75	3.79	7.57	11.36	15.15			75	$7,359,089	$17,359,089	$27,359,089	$37,359,089
		17		100	2.91	5.82	8.72	11.63			100	$6,561,012	$16,561,012	$26,561,012	$36,561,012
		18		125	2.36	4.72	7.08	9.44			125	$5,762,934	$15,762,934	$25,762,934	$35,762,934
		19													
		20 9	$1.30 9	50 9						$1.30 9	50 9				
		24													
		25	$1.50 9	50 9						$1.50 9	50 9				
		29													
		30	$1.70	50	3.69	7.37	11.06	14.74			50	$7,286,537	$17,286,537	$27,286,537	$37,286,537
		31		75	2.53	5.07	7.60	10.13			75	$6,053,144	$16,053,144	$26,053,144	$36,053,144
		32		100	1.93	3.86	5.79	7.72			100	$4,819,752	$14,558,563	$24,819,752	$34,819,752
		33		125	1.56	3.12	4.68	6.24			125	$3,586,359	$13,586,359	$23,586,359	$33,586,359

* Denotes row number; this column is blank in code.

bait prices, bait densities, and sero-positive effectiveness variables occurs in Column K [i.e., \$0.90, \$1.10, \$1.30, \$1.50, and \$1.70; (Cells K10-13, K15-18, K20-23, K25-28, and K30-33, respectively), Column L [i.e., 50, 75, 100, and 125 baits/km^2; Cells L10-13, L15-18, L20-23, L25-28, and L30-33, respectively) and sero-positive effectiveness variables in Columns M (i.e., 25% in Cells M10-13, M15-18, M20-23, M25-28, and M30-33, respectively), N (i.e., 50% in Cells N10-13, N15-18, N20-23, N25-28, and N30-33, respectively), O (i.e., 75% in Cells O10-13, O15-18, O20-23, O25-28, and O30-33, respectively), and P (i.e., 100% in Cells P10-13, P15-18, P20-23, P25-28, and P30-33, respectively), respectively. The actual prices for mode of bait distribution (i.e., FW \$8.62/km^2, RW \$33.30/km^2, and Gnd \$15.80/km^2) are coded into the formulas; these costs were derived from published literature (see Kemere et al. 2002; Foroutan et al. 2002). Expenses for machines to dispense baits were assumed to be pro-rated into the mode-of-bait distribution costs (i.e., cost of FW, RW, Gnd; \$US/km^2).

Table 1 provides a mathematical example of a specific calculation for cost, net saving, and benefit cost ratio.

Table 1. Mathematical Example

Area = 1,000 km^2
FW 40% (\$8.62/km^2), RW 20% (\$33.30/km^2), Gnd 40% (\$15.80/km^2)
Epizootic cost = \$1,000,000.00
Number of Baitings = 3 repeats
Cost/bait = \$0.90
Bait Density = 50/km^2
Sero-positive conversion among raccoons = 0.50

C	=	(Rabies-incurred Cost)
	=	\$1,000,000.00
NS	=	[(Total Rabies Cost A Sero+ Effectiveness) - (ACC + ORV)]
	=	[(\$1,000,000 A 0.50) - {[\$0.00 accidents] + {[(\$0.90 bait price A 50 baits/km^2 A 1000 km^2) + (1000 km^2 (0.40 FWA \$8.62) + 1000 km^2 (0.20 RW A \$33.30) + 1000 km^2 (0.40 Gnd A \$15.80) A 3 bait distributions]
	=	[(\$500,000) - (\$0.00 + [(\$45,000) + (\$7000 + \$6660 + \$6320)] A 3}
	=	[(\$500,000) - (\$194,940)]
	=	\$305,060
BCR	=	[(Total Rabies Cost A Sero+ Effectiveness)) (ACC + ORV)]
	=	[(\$500,000)) (\$0.00 + \$194,060)]
	=	+2.56 (i.e., savings in costs of raccoon rabies epizootic are more than double the expenses of implementing ORV with half of the raccoon population vaccinated).

A Scenario

An attempt is made to prevent a raccoon rabies outbreak in parts of Pennsylvania from spreading throughout the state. A focal point of rabid animals has been identified in several clustered counties. Raboral V-RG7 baits are to be applied over a fourth of the state radiating out from the cluster to prevent the epizootic from reaching the remaining counties.

Raccoon Rabies Potential Savings.BA key input needed to compute BCRs and NSs is the expected costs incurred due to the epizooticBthe potential savings from ORV. Our code requires input based on C ($US). For current calculations, we have used a single valueB$40 million. While this is a hypothetical C or S, it can be justified based upon empirical data.

Increased PEP and pet vaccinations are the major economic components of any rabies epizootic (Meltzer 1996). Kriendel et al. (1998) surveyed the costs of medical PEPs during a 1995 epizootic of raccoon rabies in Massachusetts, and reported that the rate of medical use for Human Rabies Immune Globulin (HRIG) went from a baseline of 17/100,000 to 45/100,000 citizens between 1991 and 1995. The cost of the HRIG (biologic) alone varied between $632 and $3,435 (median value of $1,646), but when physician and hospital emergency-room charges were added, the direct per-patient cost ranged from a low of $1,038 to a high of $4,447 (i.e., median PEP of $2,376). Using area and population data for Pennsylvania (Rand McNally 2002), converting this change in PEP incidence to 12,281,074 population for Pennsylvania yields an increase of 3,439 PEPs (17/100,000 vs 45/100,000 or a shift of 28:100,000) and expected median-based PEP costs of $8,171,064/year. Assuming that a raccoon rabies epizootic lasts 2 years (Meltzer 1996), direct PEP expenses for Pennsylvania would exceed $16 million. Add to this other direct costs for increased pet vaccinations (e.g., $5 million/year or $10 million for the epizootic), increased PH and Q expenses (e.g., $5 million/year or $10 million for the epizootic), not to mention indirect costs such as lost wages, travel expenses, and child care expenses borne by patients (e.g., $2 million/year or $4 million for the epizootic), and a total statewide cost of $40 million is easily justified.

Table 2. Input variables used for Raboral V-GR7 scenario projections.

Variable	Number of Levels	Inputs
Area baited (km^2)	1	29,021[a]
Bait price ($US/bait)	5	0.90, 1.10, 1.30, 1.50, 1.70
Bait density (n/km^2)	4	50, 75, 100, 125
Number of baitings (n)	2	1, 3
Rabies epizootic costs/savings ($US)	1	40,000,000
Mode of application (% of km^2)[c]	6	FW, RW, Gnd
FW = $ 8.62/km^2 RW = $33.30/$km^2$ Gnd = $15.80/$km^2$		100, 0, 0 0, 100, 0 0, 0, 100 50, 50, 0 50, 0, 50 0, 50, 50
Effectiveness (Sero+ %)	4	25, 50, 75, 100

[a] One-fourth the area of PA.

[b]Note.-- Bait-drop equipment included with lease rate for aircraft; FW cost from Kamere et al. (2002), RW and Gnd cost from Foroutan et al. (2002).

[c] Although 161,700 combinations of the Amode@ settings are possible, we present data for only 6 combinations of

these variables.

ORV Inputs.B As mentioned, five bait price, four bait density, and four seropositive effectiveness variables are pre-coded into the analysis (Table 2). A single input was used for the area baited (29,021 km^{2}B1/4 the state of PA) and for the potential cost savings with ORV ($40 million). Dual inputs were used for the required number of baitings needed to suppress the outbreak (1 and 3). Six mode-of-bait distribution combinations were used (RWB100%, GndB100%, FWB100%, RW-GndB50% each, RW-FWB50% each, and FW-GndB50% each).

Data Analysis

Each iteration of the code (mode-of-bait distribution) produced 80 NS and 80 BCR estimates (see Figure 1); thus, the six iterative runs yielded a total of 960 separate NS and BCR indices. These were plotted to show the three-dimensional response surface effects associated with the ORV variables.

RESULTS AND DISCUSSION

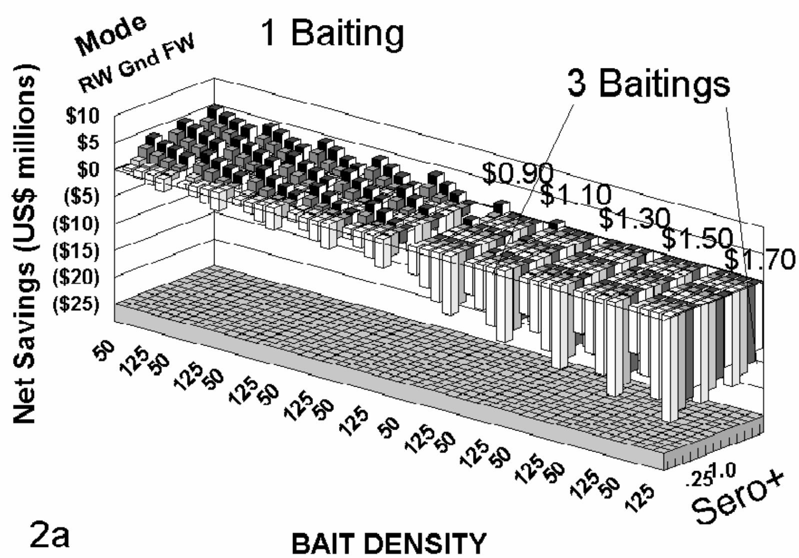
Scenario

For a single baiting involving complete bait distributions via single modes of delivery (i.e., RW, Gnd, or FW), NS values ranged from 2,866,638 to 38,447,377 (Figure 2a) and BCR values ranged from 1.40 to 25.76 (Figure 2b), respectively. The need for 3 repeat baitings to suppress the epizootic via these sole modes of delivery yielded NSs between -$11,400,085 and +$35,342,130 (Figure 3a) and BCRs between 0.47 and 8.59 (Figure 3b), respectively. The greatest NS ($3.5 to 38.4 million) and BCR (1.56 to 25.76) estimates occurred for a one-time bait distribution involving FW aircraft for the entire area.

Lower bait prices ($0.90 to $1.70), lesser bait densities (50/km^2 to 125/km^2), fewer bait applications (1 vs. 3), and greater use of the cheaper FW mode of bait distribution yielded greater NS and higher BCR indices. Regarding the iterative runs involving mode-of-bait distribution, increasingly positive NS and BCR indices occurred as the mode involved less RW or Gnd coverage relative to FW aircraft (i.e., RW < Gnd also yielded transitivity). This same effect of inversely higher NS and BCR values was also observed for the dual modes of distributions (i.e., RW-Gnd, RW-FW, and FW-Gnd yielded lower NS and BCR values, respectively).

These results readily show how economic impacts are dependent upon the relative price structure involved in ORV. Bait price, bait density, mode of distribution, and repeated baiting interact to determine current ORV cost effectiveness. At present, production of Raboral V-RG7 baits are labor intensive and involve individual preparation. Sale to federal sources (United States Department of Agriculture 2001) is set at $1.27/baitBa price associated with BCRs >3.0 for all RW, Gnd, and FW bait distributions involving a single application. The required density of baits needed to successfully vaccinate a sufficient segment of a raccoon population so as to create a rabies-free zone (Abarrier@) or to Aeliminate@ the disease is unknown. This question is receiving intense research interest (see Kemere et al. 2002, Slate et al. 2002). All of our computer runs involving #125 baits/km^2 produced >2.0 BCRs at bait prices <$1.30.

Figure 2. A 3-dimensional graph of the response surface for (a) potential net savings and (b) potential benefit-cost ratios showing the effects of 1 and 3 repeated baitings with 100% RW, Gnd, and FW mode-of-bait distributions over 29,021 km^2.



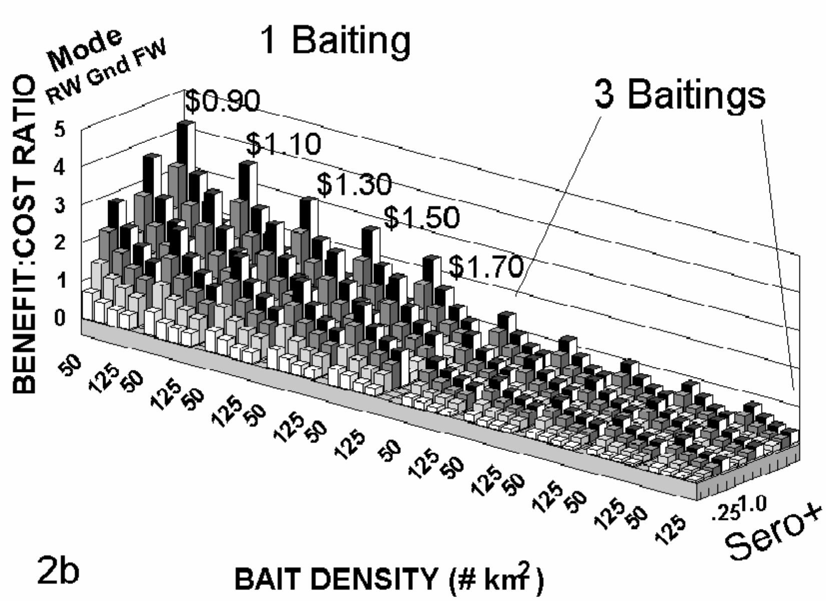
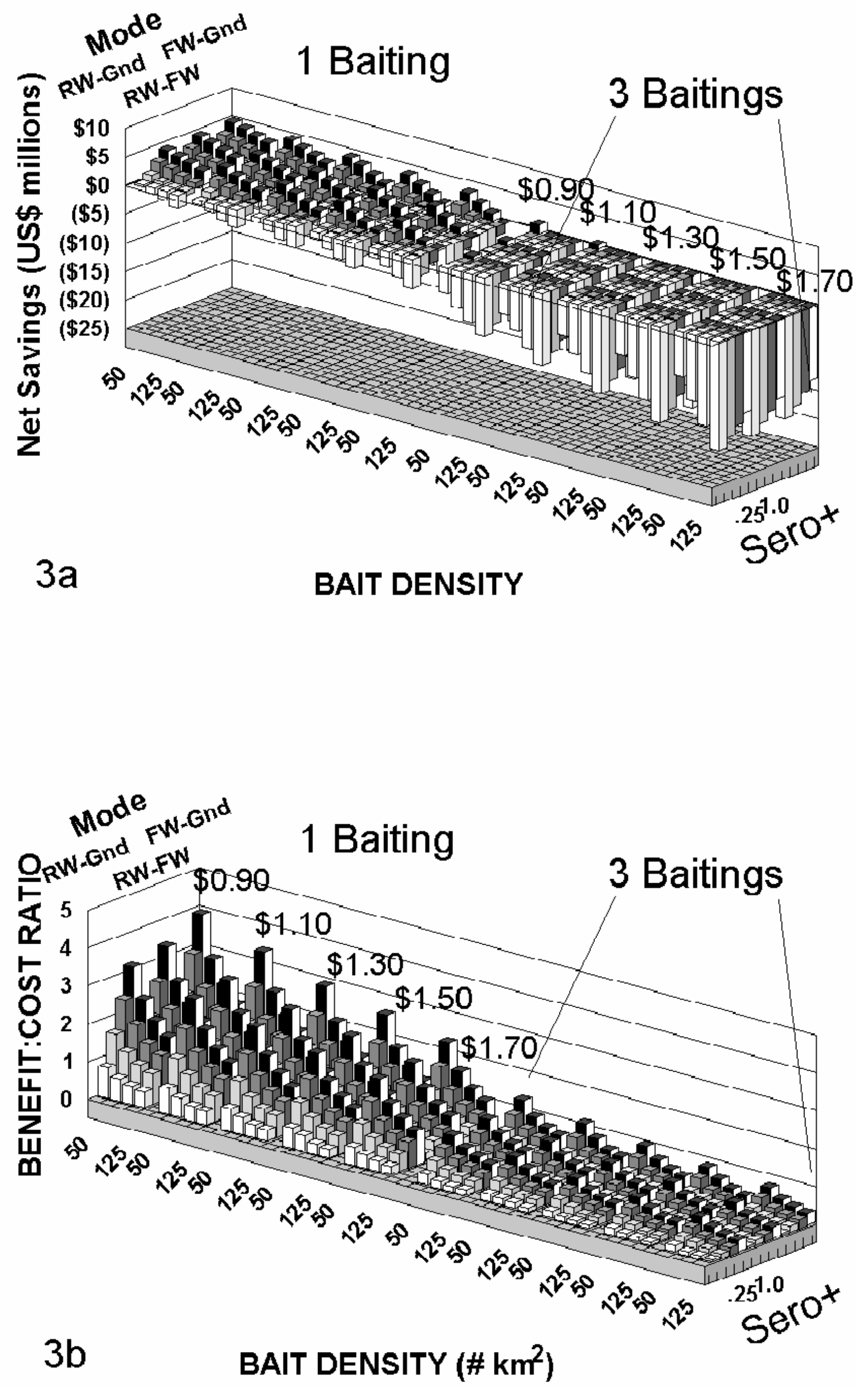


Figure 3. A 3-dimensional graph of the response surface for (a) potential net savings and (b) potential benefit-cost ratios showing the effects of 1 and 3 repeated baitings with 50-50% RW-Gnd, RW-FW, and FW-Gnd mode-of-bait distributions over 29,021 km^2.



Approach

Our scenario results demonstrate the utility of using spreadsheet projections to evaluate potential economic impacts of Raboral V-RG7 bait distributions for containing or eliminating raccoon variant rabies in the Eastern U. S. Despite numerous assumptions, we contend that our iterative projections of NS and BCR indices reduce the economic uncertainty associated with ORV. The approach affords a quick, relatively inexpensive tool for modeling diverse ORV scenarios. The graphical and tabular displays of a range of NS and BCR indices for variables involved in ORV afford decision heuristics to be set up that ensure improved applications of the technology (e.g., keeping RW- and Gnd-based bait distributions to <30% of the total area, limit bait densities to <75/km^2). This approach shows how bait price, bait density, bait frequency, and bait effectiveness relate to overall cost effectiveness of ORV.

A major implication of our scenario analysis is that more accurate estimates of the total costs which raccoon variant rabies exert on the U. S. economy are sorely needed. These costs are critical to any determination of potential ORV benefits. Also, realistic economic approaches to determining the pay-back scheme for wide-area ORV strategies need to be identified. Empirical studies of not only direct, but indirect and induced costs/savings, associated with raccoon variant ORV will offer more precision for future analyses; whereas, pro-rated, multi-year benefits from ORV may more accurately characterize these returns on investments (Meltzer 1996). While our use of a two-year, $40 million cost-savings value for a Pennsylvania focal outbreak was intentionally conservative, this scenario is a simple Asnap-shot@ of how ORV benefits may impact future economies. Still, even this showed that 1 or 3 bait distributions over one-fourth of the state could yield significant savings and multiple returns on expenses assuming a specific bait price, density, and mode of distribution.

Kemere et al. (2002) modeled the economic benefits of creating a hypothetical zone of vaccinated raccoons as a Abarrier@ to the westward spread of the disease using Raboral V-RG7 (Merial Limited, Athens, Georgia, USA) baits. The zone was viewed to encompass 102,605 km^2 and parallel areas along western parts of the Appalachian Ridge. A benefit-cost approach was used that assumed a 20-year period for creation and maintenance of the barrier. Estimates of diverse surveillance, medical, veterinary, and evaluation costs were compared to estimates of bait-application costs under four models, with potential savings tied to reduced need for these outlays west of the barrier. Four models specified either a 40.2 (Models A and B) or a 127.1 (Models C and D) km/yr spread of raccoon variant rabies with or without the potential costs for epizootic-induced veterinary prophylaxis of domestic animals, respectively. Under these scenarios, program costs totaled $95.7 million; whereas, net benefits (discounted at 7%/yr) ranged between $48 and $496 million, depending upon whether bait applications continued unchanged or were scaled back (larger net benefits) after initial set up of the zone. Sensitivity analyses yielded mean (SD) net benefits of 202 (4.10), 109 (4.11), 496 (4.07, and 313 (4.07) for Models A, B, C, and D, respectively.

CONCLUSIONS

Using a raccoon rabies epizootic suppression scenario for parts of Pennsylvania and a modest epizootic cost estimate of $40 million, ORV was projected to yield NS values >2.8 million and BCR values >1.4, respectively. If numerous assumptions are made, Excel7 XP software can be used to make projections of NS and BCR associated with ORV. Using the code we have generated, graphical and tabular displays of the response surfaces for key variables and numerous scenarios can be performed quickly. The approach offers a useful analytical tool for identification of critical cost thresholds for the myriad of cost factors that affect ORV. The potential for simple heuristics to be devised that govern profitable/non-profitable applications of ORV should be a future asset.

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on the draft manuscript. Use of trade name products does not imply endorsement by the U. S. Government.

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