

The Economics of Managing Infectious Wildlife Diseases when Livestock are at Risk: Preliminary Results

Richard D. Horan and Christopher A. Wolf

Department of Agricultural Economics

Michigan State University

Kenneth H. Matthews, Jr.

ERS – USDA

Diseases transmitted via a wildlife population are a growing problem worldwide

Concern over risks to

Human health

Livestock

Recreation/hunting

Conservation of biodiversity










Bovine Tuberculosis (TB) in Michigan Deer

- Only known area in North America where bovine TB is established in wild deer
- Deer have infected a number of cattle herds.
 - Agricultural damages estimated at \$12 million/year
- Policy responses
 - Reduce deer herd
 - Stop supplemental feeding





BOVINE TUBERCULOSIS SURVEY RESULTS

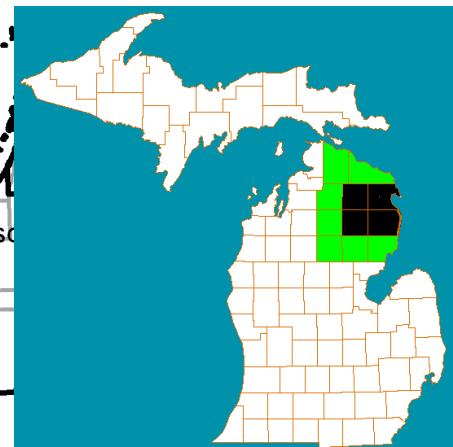
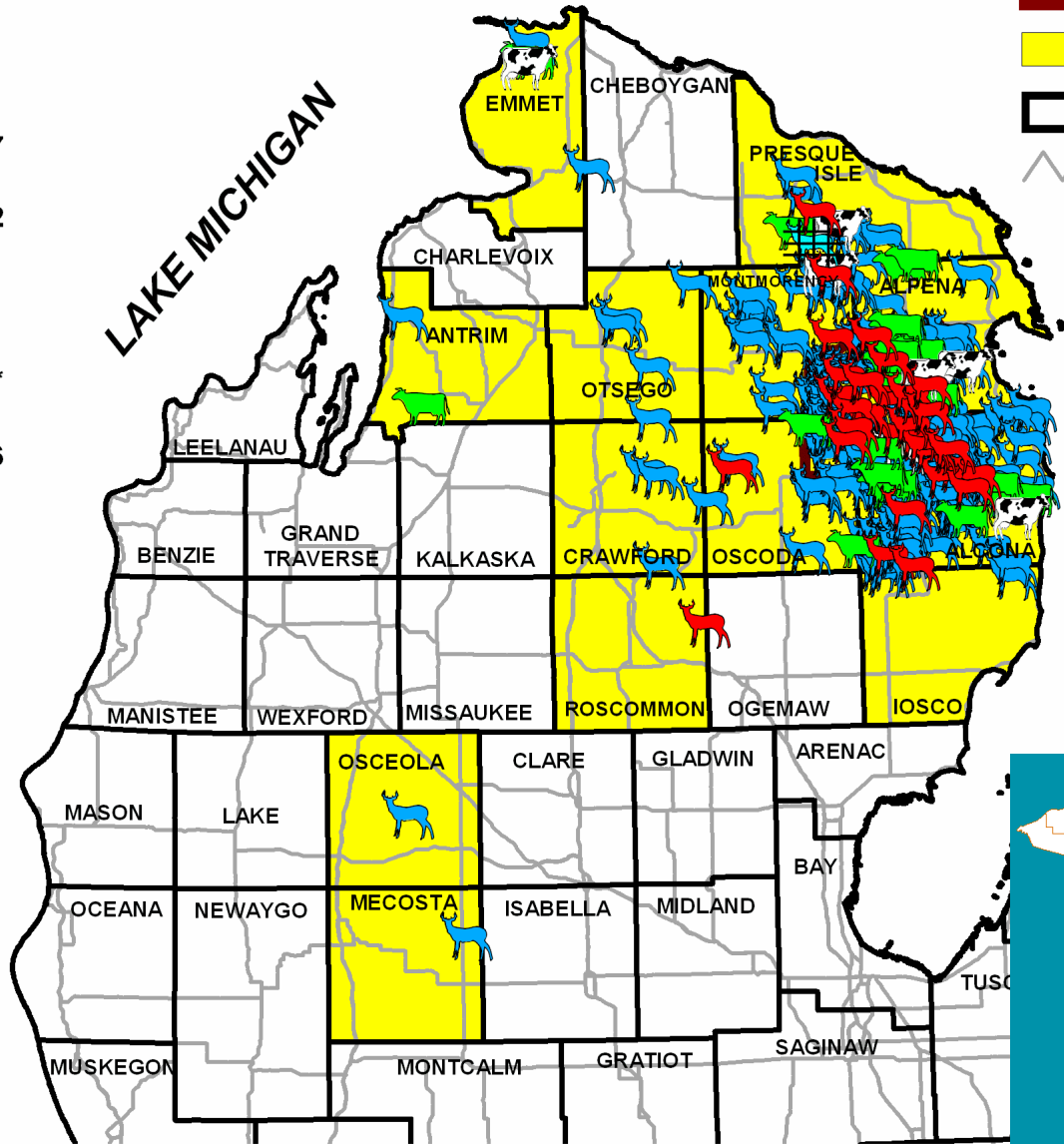
- White-tailed Deer and Cattle -

NUMBER

-  1975 POSITIVE TB DEER 1
-  1994 POSITIVE TB DEER 1
-  1995-2002 POSITIVE TB DEER 447
-  2003 POSITIVE TB DEER 32
-  1997 POSITIVE CAPTIVE DEER HERD 1
-  1998-2003 POSITIVE BEEF CATTLE HERD 26*
-  2000-2003 POSITIVE DAIRY HERD 6

*Total includes twice affected farms

-  NEW (2001) DMU 452
-  TB INFECTED COUNTY
-  COUNTY LINES
-  HIGHWAYS



Model of optimal management



Bioeconomic model of deer and cattle, incorporating disease transmission



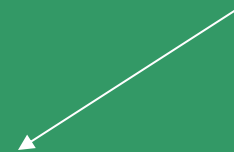
Decentralized model



Analyze private incentives and impacts in unregulated case



Analyze incentives created by existing policy approaches, and impacts



First-best and second-best policy options

Prior research on wildlife transmitted disease

- Little regard given to wildlife dimension
 - Estimates of costs to farmers and consumers from diff't control strategies (e.g., depopulation, test and remove) and resulting trade and market effects
- Bicknell et al. (*Aus. J. Agr. Res. Econ.* 1999)
 - Bioeconomic model of possum and dairy cow populations
 - Optimal disease control strategies from a single farmer's perspective
 - Selective harvesting of diseased possums possible
 - Possums have no real value (other than nuisance)

(Some) Research gaps

- Social optimum
 - Most problems faced jointly by many farmers
 - Wildlife-related benefits also important
 - High recreational values (hunting)
 - Threatened and endangered species
 - Wildlife eradication policies may be expensive
- Non-selective harvesting of infected wildlife
 - Offtake accompanied by healthy and valuable animals
 - Increases disease control costs
 - More difficult to exterminate diseased animals
 - Alters disease dynamics in a sub-optimal fashion.

Outline of basic model

- Two state variables
 - Deer population, N
 - Prevalence rate in deer, θ
- Two control variables
 - Aggregate harvest, h
 - Non-selective with respect to disease
 - By itself, harvesting cannot eliminate a persistent disease (without eradicating all wildlife in the area)
 - Supplemental feeding, f
 - Increases *in situ* productivity (diminishes density-dependence)
 - Non-selective with respect to disease
 - Increases transmission
 - Decreases disease-related mortality



Social planner's problem

- $NB(t) =$ value of hunting – costs of hunting – costs of feeding – damages to livestock sector
- Objective function: $Max_{h,f} \int_0^{\infty} NB(t)e^{-\rho t} dt$
subject to the equations of motion
- Linear control model

Double singular solution

- Adjoint equations for N and θ yield “golden rule” equations (in implicit form):

$$\rho = F(N, \theta, f), \quad \rho = G(N, \theta, f, h)$$

- Solve for nonlinear feedback laws for controls, $f(N, \theta)$ and $h(N, \theta)$
- Plug $f(N, \theta)$ and $h(N, \theta)$ into the equations of motion for N and θ , and solve the differential equations

$$\dot{N} = A(N, \theta), \quad \dot{\theta} = B(N, \theta), \quad N_0, \theta_0$$

- Note: solution depends on initial states, N_0 and θ_0

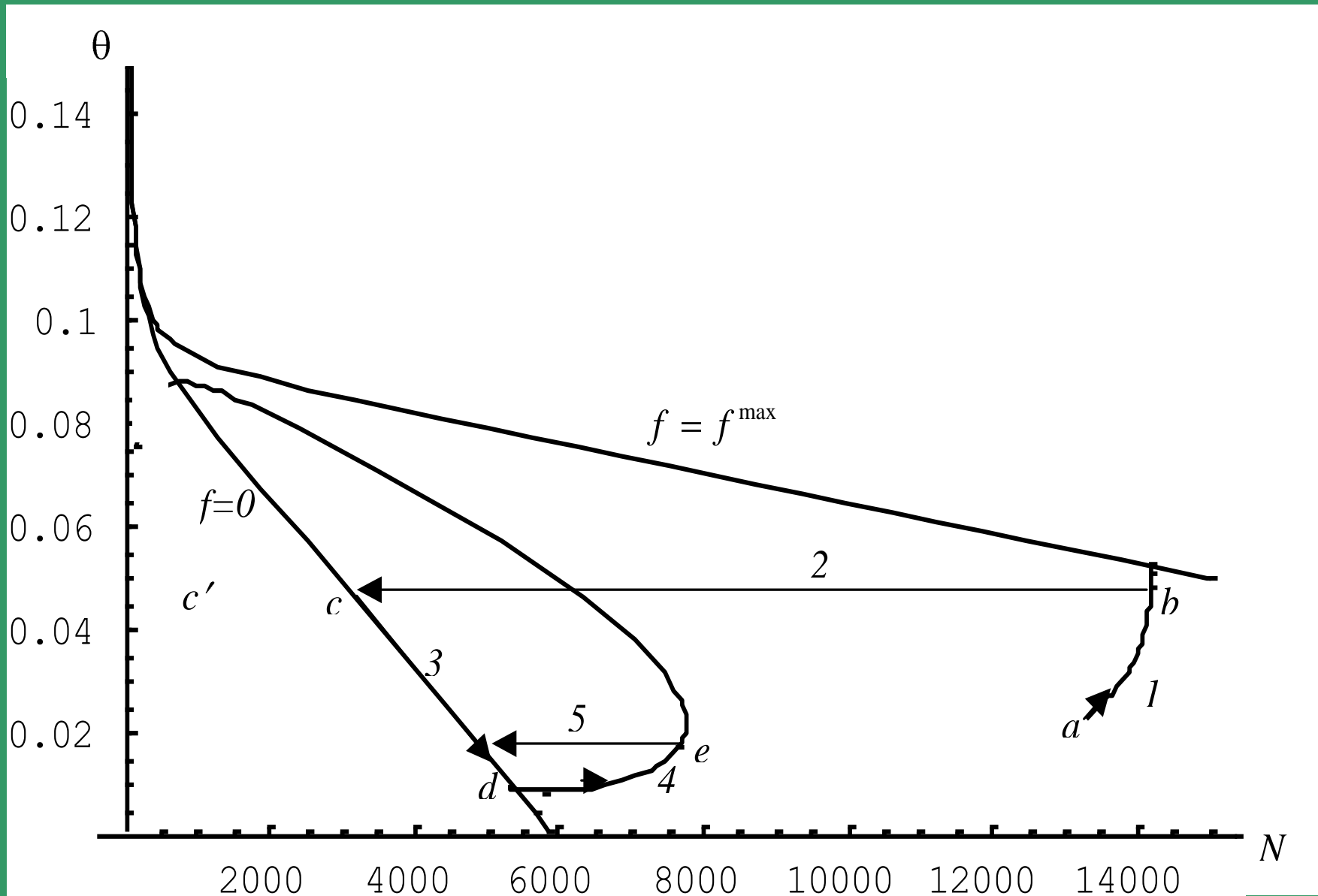


Figure 1. Solution of the benchmark numerical example

Some results of basic model

- Disease eradication may not be optimal
- Feeding bans to quickly reduce/eliminate the disease may be too costly
 - Opportunity cost of forgoing productivity investments (via feeding) may be too large
 - Feeding is an investment in deer productivity
 - Intermittent investments create opportunities for near-term gains
 - Similar to Clark, Clarke, and Munro (1979), although investment in our model produces adverse affects on resource dynamics

Adding the livestock (cattle) sector

- On-farm biosecurity and stocking decisions affect damages

Results

- Cost-effective to target cattle sector for risk-reduction
 - Direct cattle risk controls vs. non-selective deer-related controls
 - Cattle sector is not highly profitable
- Reduce risk of transmission to livestock to zero
 - Fully invest in biosecurity or permanently remove all cattle from infected region
 - Deer are managed independently
 - Deer are highly valued whereas cattle sector is not valuable
 - Only damages are to hunters; can support greater prevalence in deer
 - Only have cattle sector if profitability exceeds investment cost

Targeting risk by sex of deer

- Prevalence in deer varies by sex
 - Male/female behavioral differences affect transmission
- Sex-based harvests target important risk factor
 - Reduces wildlife disease control costs
 - Disease eradication might be optimal
(assumed no adjustments in the cattle sector)

Summary of results from expanded models

- Better risk targeting in wildlife sector increases likelihood that it will be optimal to
 - eradicate disease in wildlife
 - preserve cattle sector
- Better risk targeting in livestock sector increases likelihood that it will be optimal to
 - eliminate inter-species transmission
 - Possibly eliminate cattle sector
 - allow endemic disease in wildlife

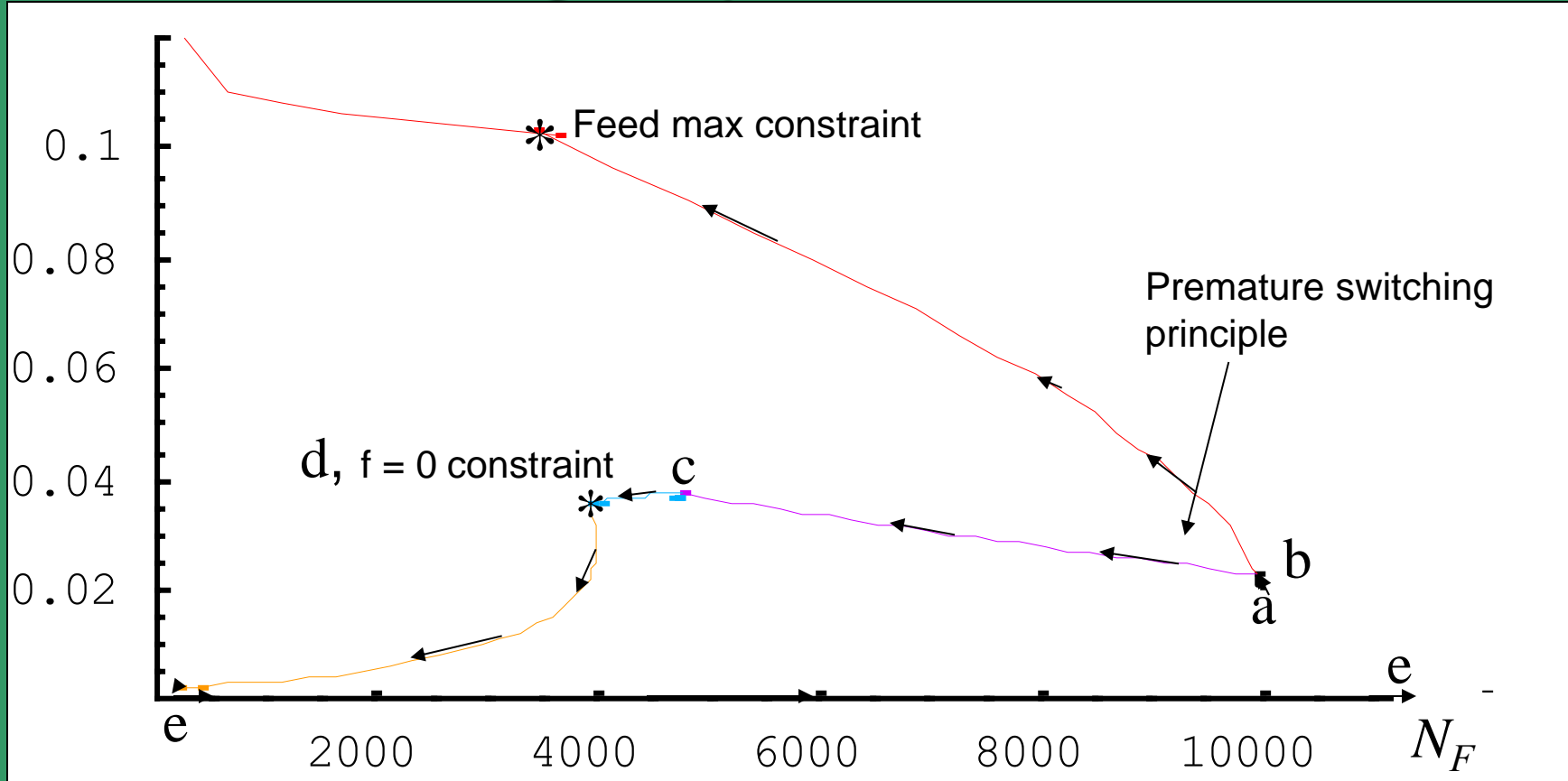
Research outputs

- Horan, R.D. and C.A. Wolf, “The Economics of Managing Wildlife Disease”. Under 2nd round review at *American Journal of Agricultural Economics*
- Horan, R.D., C.A. Wolf, E.P. Fenichel, and K.H. Matthews, Jr., “Wildlife and Livestock Disease Control with Inter-and Intra-Specific Transmission and Endogenous On-Farm Biosecurity”, Selected paper, the annual meetings of the American Agricultural Economics Association, Denver, CO, August 1-4, 2004.
- Fenichel, E.P., R.D. Horan, and C.A. Wolf, “The Role of Sexual Dimorphism in the Economics of Wildlife Disease Management”, Selected paper, the annual meetings of the American Agricultural Economics Association, Denver, CO, August 1-4, 2004.
- Fenichel, E.P., R.D. Horan, and C.A. Wolf, “Wildlife Disease Management Policies Based on Sexual Dimorphism: An Economic Argument” Selected paper, the annual conference of The Wildlife Society, Calgary, AB, Canada, September 18-23, 2004.

Future work

- Spatial management
 - Opportunities to better target risks
 - Consideration of additional risks of spread
- Decentralized model of farmer/hunter behavior
 - Examine economic incentives faced by individuals
 - Role of policy

After transforming the problem in terms of females



Path description

1. Original path- feeding unconstrained, $0 < \text{♀ harvests} < \text{all } \text{♀}$, $0 < f < \text{max}$ (optimal) ($t = 0.5$, at **b**)
2. Original path- feeding unconstrained, $0 < \text{♀ harvests} < \text{all } \text{♀}$, $0 < f < \text{max}$ (sub -optimal)
3. Feeding constrained at max, 1 , $0 < \text{♀ harvests} < \text{all } \text{♀}$, $f = \text{max}$ ($t = 1.5$, at **c**)
4. Unconstrained feeding path reemerges, $0 < \text{♀ harvests} < \text{all } \text{♀}$, $0 < f < \text{max}$ ($t = 2$, at **d**)
5. Feeding constrained at zero path 2, $0 < \text{♀ harvests} < \text{all } \text{♀}$, $f = 0$ ($t = 22$, at **e**)
6. Bang - bang solution $\text{♀ harvests} = 0$, $\text{♂ harvests} = 0$, $f = \text{max}$ ($t \text{ ♂} = 30$, $t \text{ ♀} = 45$ at **g**)