Strategic Agent Behavior with an Invasive Weed

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Will agents manage an invasive species before it becomes an economic problem?

What is the optimal strategy?

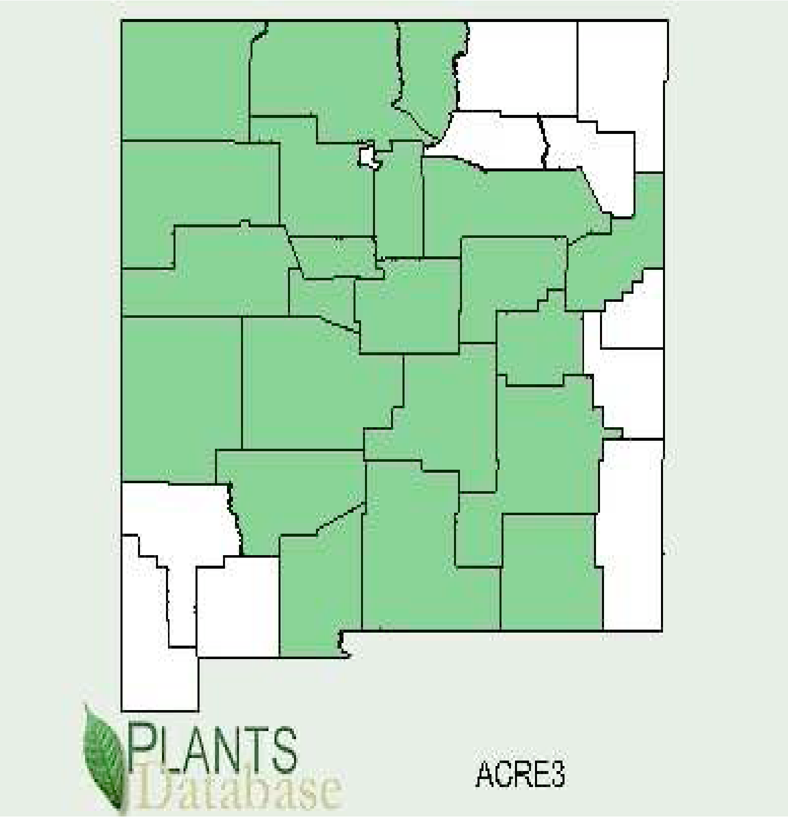
How do neighbors' actions impact decisions?

Are incentives provided?

RESEARCH PLAN

- Focus on invasive weeds in NM that are not yet an economic problem
  - Russian Knapweed
  - Yellow Starthistle

Russian Knapweed



Yellow Starthistle

Source: http://plants.usda.gov

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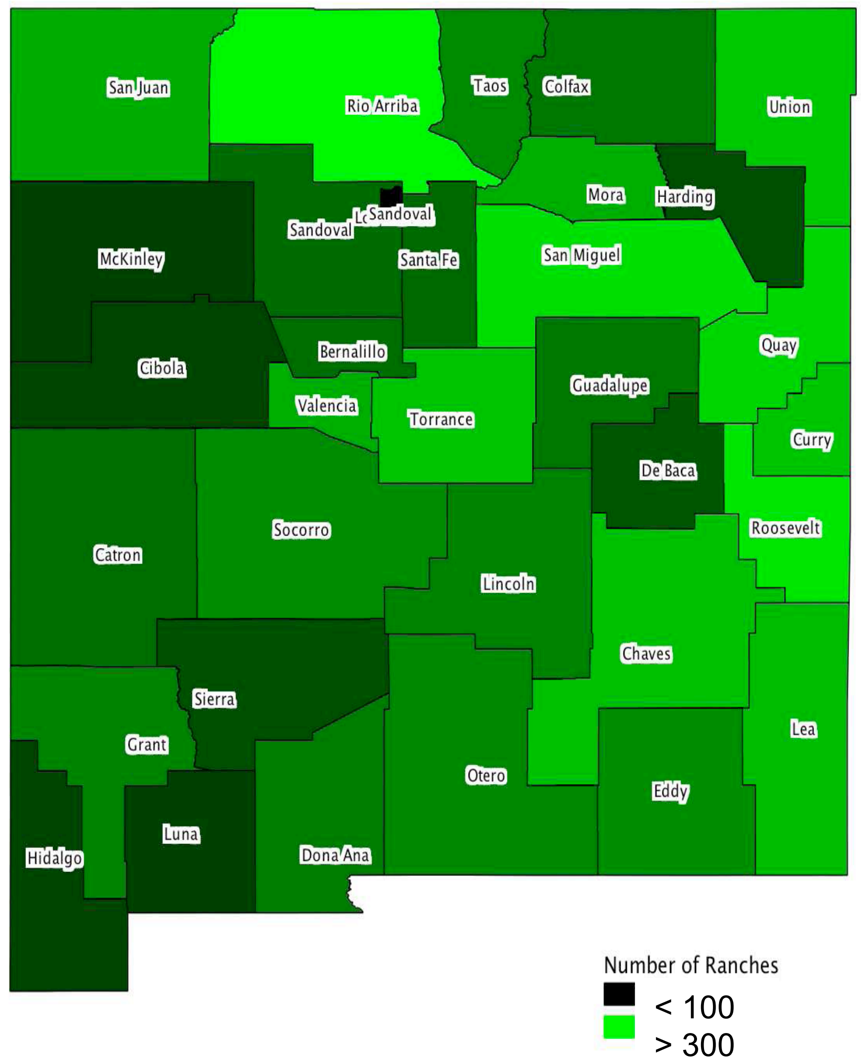
RESEARCH PLAN

- Focus on invasive weeds in NM that are not yet an economic problem
  - Russian Knapweed
  - Yellow Starthistle
- Focus specifically on cattle ranching

NUMBER OF RANCHES



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RESEARCH PLAN

- Focus on invasive weeds in NM that are not yet an economic problem
  - Russian Knapweed
  - Yellow Starthistle
- Focus specifically on cattle ranching
- Employ a multi-faceted approach
  - Theoretical and Numerical Modeling
  - Surveys
  - Economic Experiments
  - Numerical Modeling

DYNAMIC NON-COOPERATIVE GAME

Agent *i*'s Problem
Maximize Net Benefits:

$$J_i\left(\theta_{i,0};\left[w_i(t),\mathbf{w_j}(t)\right]_0^T\right)=\int_{t=0}^{T} e^{-r_i t}\left[B_i(\theta_i(t),w_i(t);\mathbf{A_i})\right]dt$$

subject to:

$$\dot{\theta}_i(t)=f_i\left(g_i(\theta(t)),\mathbf{w}(t),\psi\right),\theta_i(0)=\theta_{i,0}$$

where:

- *i,j* private agents (ranchers) (*i does not equal j),*
- $\theta_i(t)$ defines *i's* stock of the invasive species (state),
- $w_i(t)$ denotes the management effort of agent *i* during *t* (control),
- $\mathbf{A_i}$ is a vector of *i's* characteristics, and
- ψ is the effectiveness of management.

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Each agent observes the current conditions and chooses the optimal management level consistent with

$$w_i(t) = \eta_i(\theta_i(t)).$$

A Nash equilibrium occurs if

$$J_i\left(\theta_{i,0};\left[\eta_i^*(\theta_i(t)),\eta_j^*(\theta_j(t))\right]_{t=0}^{T}\right) \geq J_i\left(\theta_{i,0};\left[\eta_i(\theta_i(t)),\eta_j^*(\theta_j(t))\right]_{t=0}^{T}\right)$$

At this level of generality we can say little concerning the characteristics of the optimal effort path for an individual agent.

Specific functional form - three models:

Open-loop
Closed-loop, open-form (dynamic simulations)
Closed-loop, closed form (LQ form)

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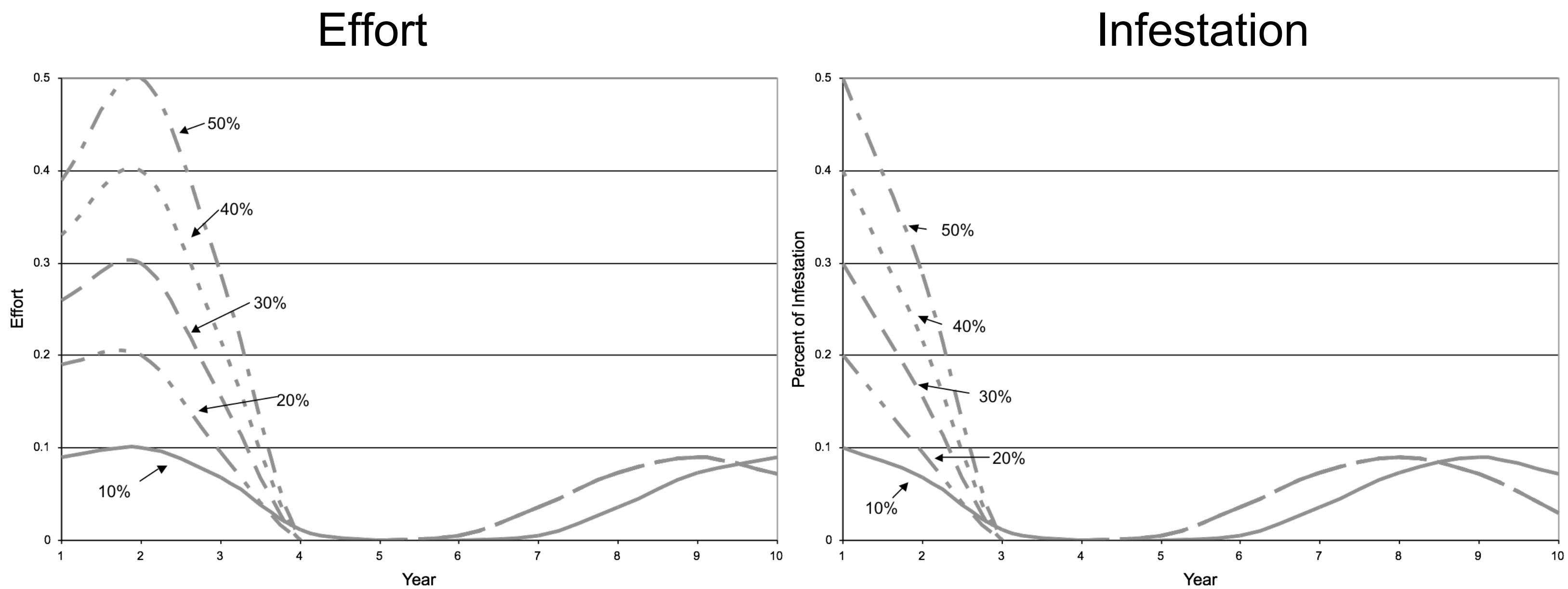
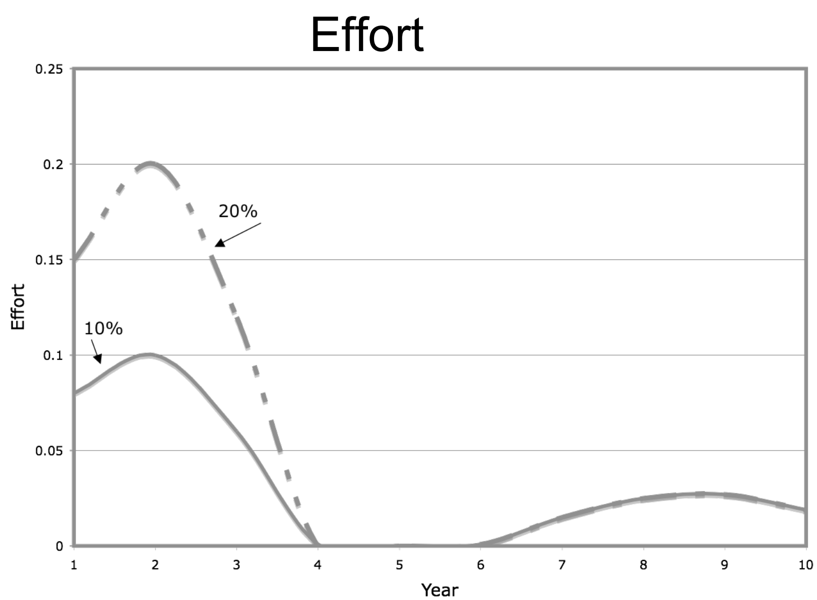
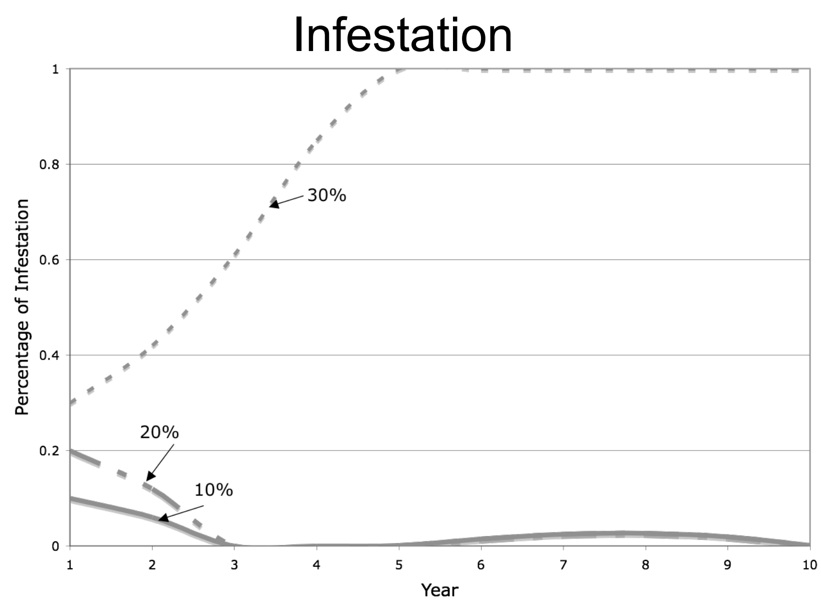
Base Case Results (closed-loop, open-form)



Initial Infestation (%)	Percent of Initial Infestation Eradicated	NPV ($)	Average Cost of Effort ($/Acre)	Cost Range	
				Min	Max (level)
10	90	714.10	2.92	0.00	8.55
20	95	712.75	8.23	0.00	37.05
30	87	552.36	16.20	0.00	72.80
40	83	427.06	27.21	0.00	120.45
50	78	271.27	41.18	0.00	187.58

Low Carrying Capacity





Initial Infestation (%)	Percent Initial Infestation Eradicated Low CC	Percent Initial Infestation Eradicated Base CC	Difference in Initial Period Eradication	NPV ($) Low CC	NPV ($) Base CC	Difference NPV ($)
10	80	90	-10	100.37	714.10	-613.73
20	75	95	-20	50.60	712.75	-662.15
30	0	87	-87	25.92	552.36	-526.44

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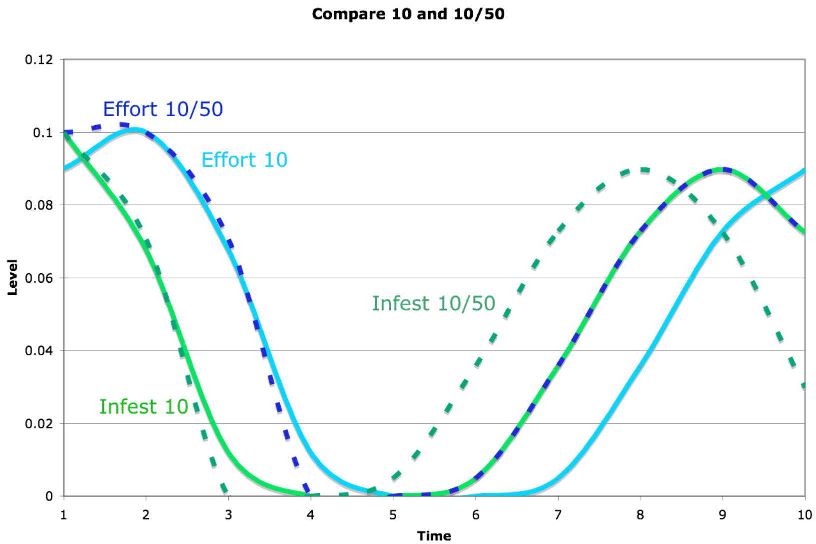
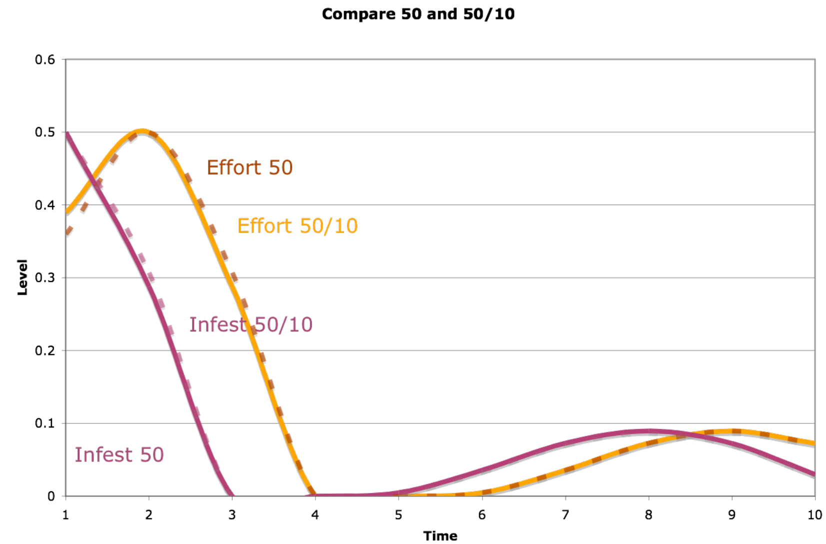
Asymmetric Agents





Initial Infestation (%)		Percent of Initial Infestation Eradicated		NPV ($)		Average Cost of Effort ($/Acre)		Cost Range			
								Min		Max	
i	*j*	*i*	*j*	*i*	*J*	*I*	*j*	*i*	*j*	*i*	*j*
10	20	90	90	714.10	647.84	2.94	8.77	0	0	8.55	34.12
10	30	80	83	711.00	553.97	3.03	15.98	0	0	8.65	68.75
10	40	100	75	708.67	431.24	3.30	26.58	0	0	10.00	121.78
10	50	100	72	707.86	278.56	3.34	40.27	0	0	10.00	192.13

Summary of Numerical Results

Baseline:
• Can manage infestation, high initial effort optimal

Low CC
•Infestation< 30%, can manage
•Infestation > 30%, no optimal management solution
•Increased time horizon results in higher infestation level solutions

Asymmetric Agents
• High infestation agent realizes positive externalities from low infestation agent
• Low infestation agent needs to exert more effort

Do ranchers follow optimal strategies?

SURVEY
Choice Question Example

	Russian Knapweed	Yellow Starthistle
Reduction in carrying capacity if not managed	5%	15%
Probability infestation spreads to area ranches, if not managed	Medium	Low
Percent of area ranches managing this weed	50%	90%
Degree of infestation in local area	Medium	Light
Total weed management cost	$1000	$2500

I would be more likely to: *Check one*

1 Manage the Yellow Starthistle infestation
2 Manage the Russian Knapweed infestation
3 Not manage either infestation
4 Manage both infestations

<u>Attribute Levels:</u>

- Carrying Capacity: 5%, 15%, 30%
- Probability Spread: Low, Medium, High
- Percent Others Managing: 10%, 50%, 90%
- Local Infestation: Light, Medium, Heavy

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Example Results

Parameter	All data Estimate	Std Err	P-values		RK/YS choices only Estmate	Std Err	P-values	
Russian Knapweed								
AreaInfest: Heavy	0.34	0.11	<0.01	***	0.47	0.18	0.01	***
AreaInfest: Medium	0.33	0.11	<0.01	***	0.24	0.18	0.19	
α_{RK}	0.057	0.11	0.60		0.16	0.16	0.34	
Yellow Starthistle								
AreaInfest: Heavy	0.047	0.107	0.66		0.11	0.18	0.56	
AreaInfest: Medium	-0.035	0.108	0.74		0.16	0.18	0.37	
Other								
Othr	0.037	0.010	<0.01	***	0.052	0.017	<0.01	***
$Othr^2$	-0.0017	0.0042	0.68		-0.010	0.0075	0.15	
Sprd: High	0.22	0.077	<0.01	***	0.48	0.12	<0.01	***
Sprd: Medium	0.17	0.072	0.02	**	0.32	0.12	0.01	***
CCN	0.33	0.034	<0.01	***	0.63	0.062	<0.01	***
CCN^2	-0.054	0.045	0.22		-0.15	0.073	0.04	**
Cost	-0.021	0.0021	<0.01	***	-0.027	0.0035	<0.01	***
α_N	-0.93	0.14	<0.01	***				
α_B	1.50	0.12	<0.01	***				
N		2602				961		
LogL		-2926.61				-543.18		

*, **, and *** denote significant estimates at the 10, 5, and 1 percent levels, respectively.

All continuous variables, *Othr* and *CCN* are centered.

From the survey we find

Ranchers are:

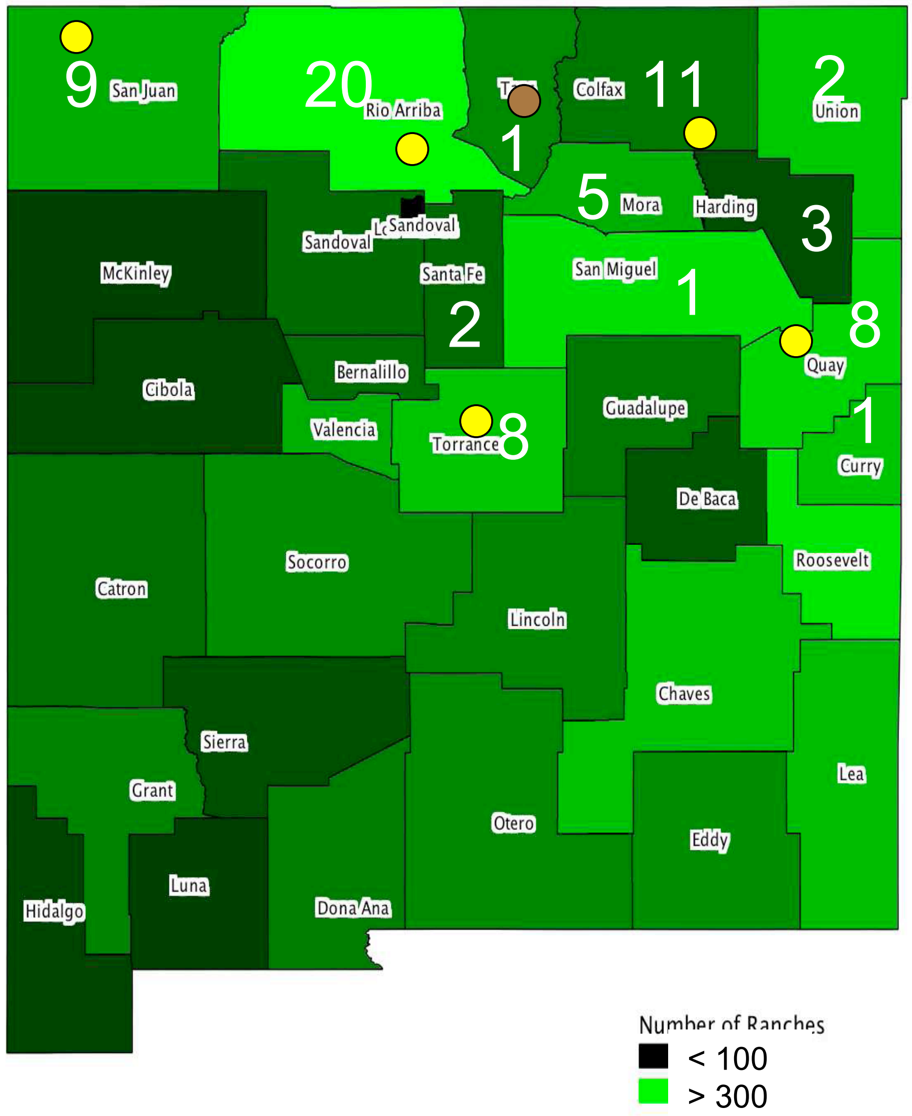
- more likely to manage the higher the level of infestation
- more likely to manage weeds when their neighbors are
- more likely to manage weeds if not managing negatively impacts neighbors

In addition:

- size of ranching operation matters
- there are regional differences within the state
- share of family income from ranching impacts results
- type of weed matters

How do ranchers act in a multi-round experiment?

EXPERIMENTAL LOCATIONS



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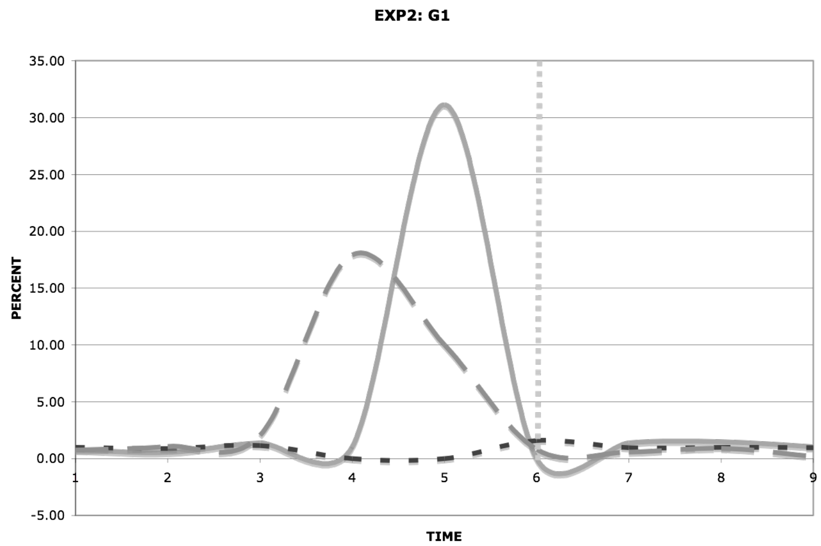
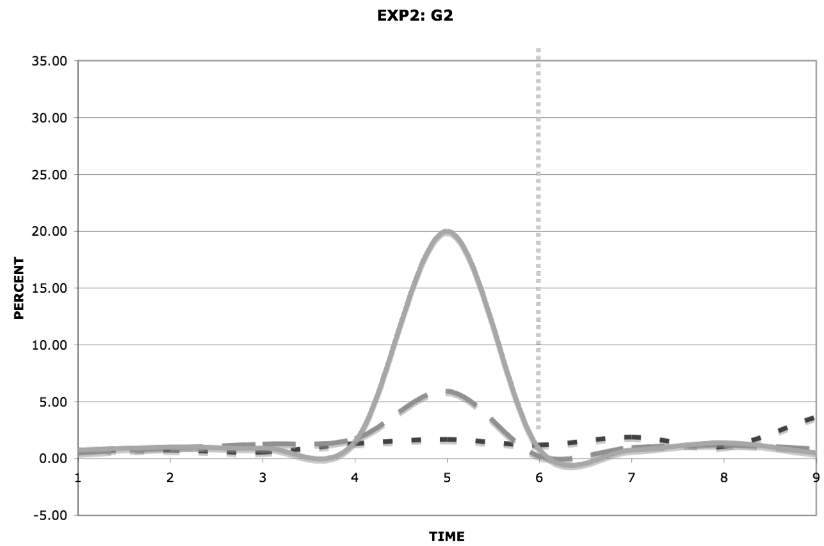
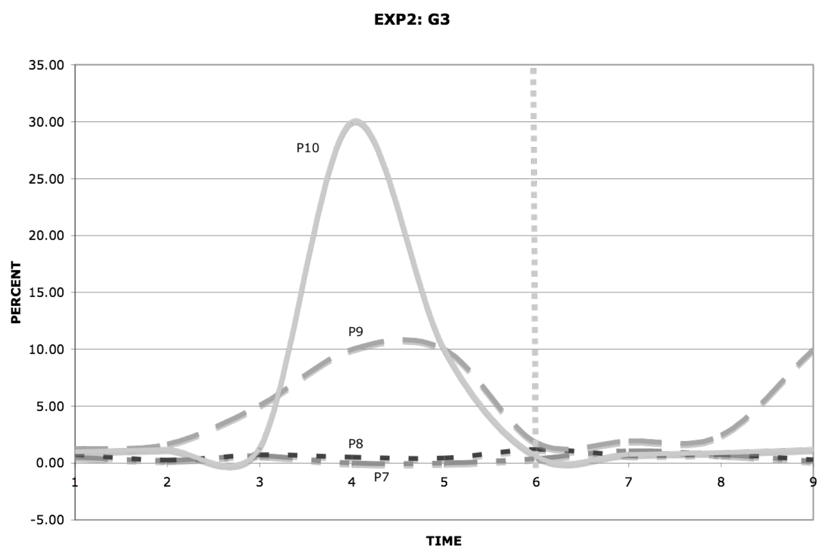
Experiment 2 (North West NM)







Ratio of Effort to Infestation

= 0: no effort

= 1: effort equals infestation level

> 1: effort > infestation level

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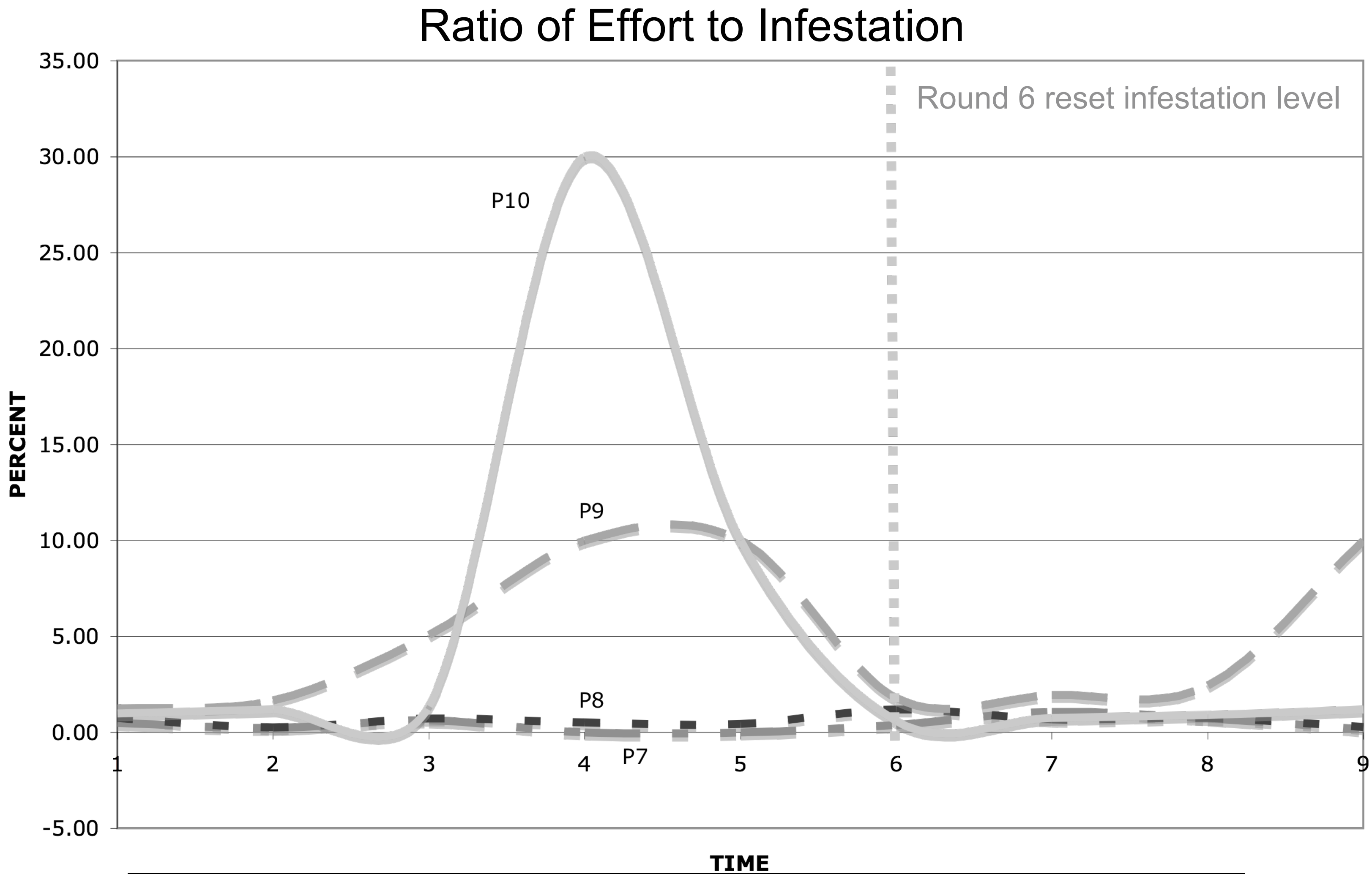
EXP2: G3



Part	Horizon	Acres	Herd	Graze	Yrs	Age	Gend	Educ.	Eth	Pol
P7	10	<50	20	Private	16	64	F	<HS	Hisp	Rep
P8	5	<50	10	Private	15	61	F	HS	Ang	Dem
P9	50	3160	200	Both	10	63	F	HS	Ang	Dem
P10	5	165	20	Private	35	67	F	<HS	Ang	Rep

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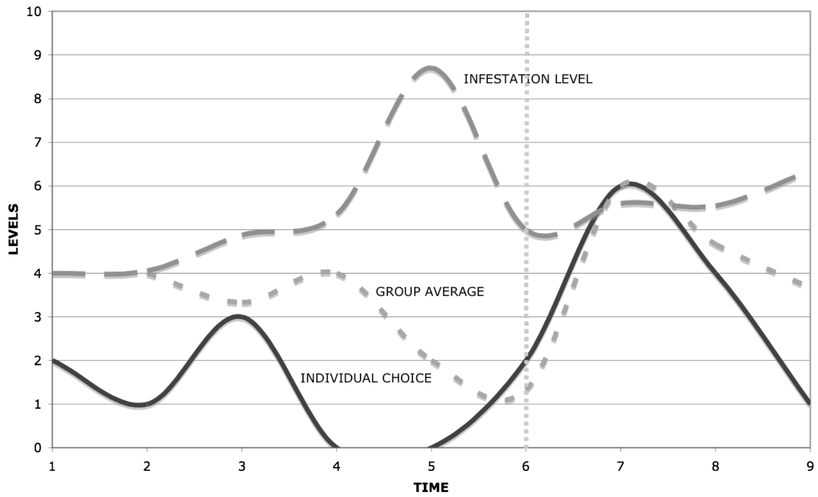
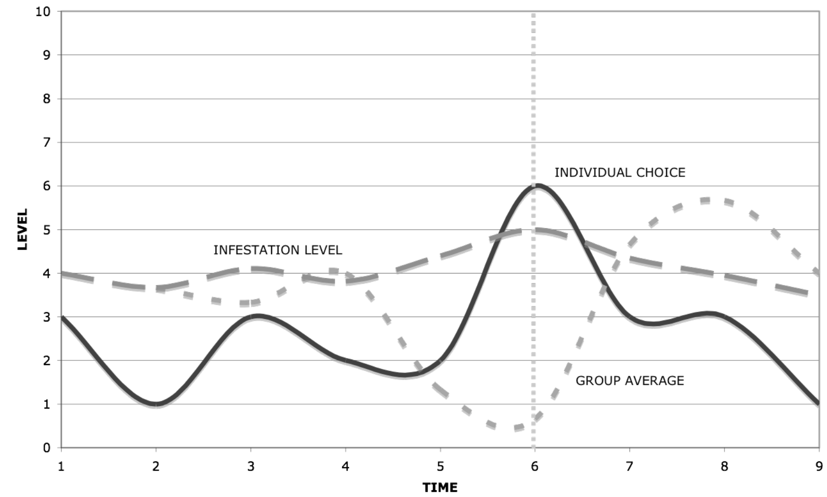
EXP2 G3

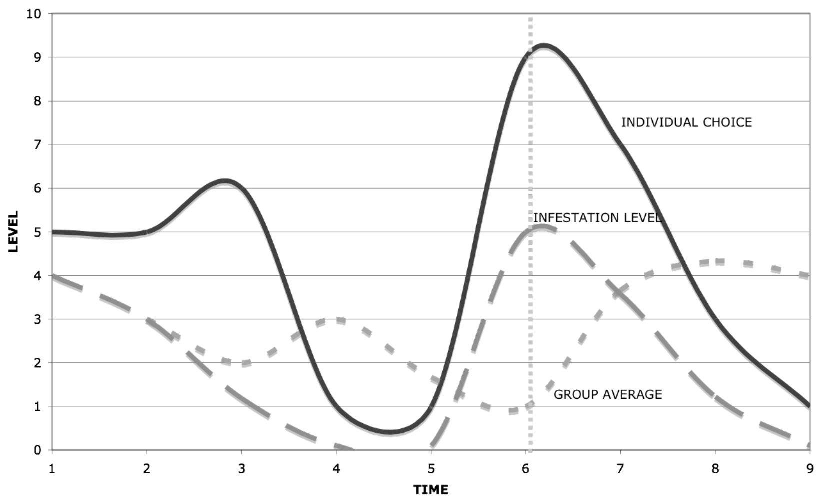
PARTICIPANT 7



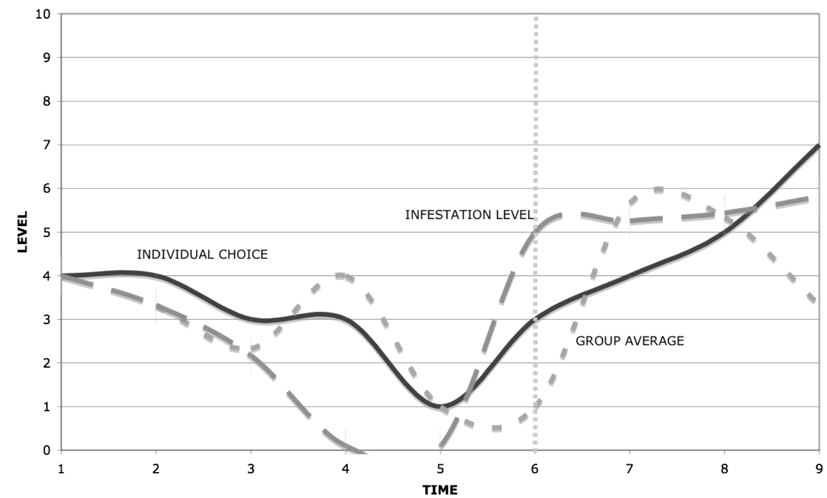
PARTICIPANT 8



PARTICIPANT 9



PARTICIPANT 10



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SUMMARY

Factor	Modeling	Survey	Experiments
Early Action	Relatively Aggressive	Depends on level of infestation	Varies across participants
Neighbors' Actions	If inaction, need to compensate	More likely to act if neighbor acts	Varies across participants
Strategy	Changes as problem changes	Impacted by infestation, neighbors, location, individual characteristics	Ranges from aggressive to free-riding

CONCLUSIONS

WEED MANAGEMENT PROGRAMS (PRE-ECONOMIC PROBLEM)

- education
- adaptable to heterogeneity
- menu of incentives

ONGOING WORK

- complete experimental analysis
- informed (from surveys and experiments) numerical modeling
- spatial variation
- uncertainty
- changing preferences
- changing characteristics
- group composition
- …..

THANK YOU

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