POTTSGROUP QUANTIFYING SUSTAINABLE ECOSYSTEM MANAGEMENT

Interactive Dynamics of Wildlife Populations, Human Health and Household Wealth

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Acknowledgments

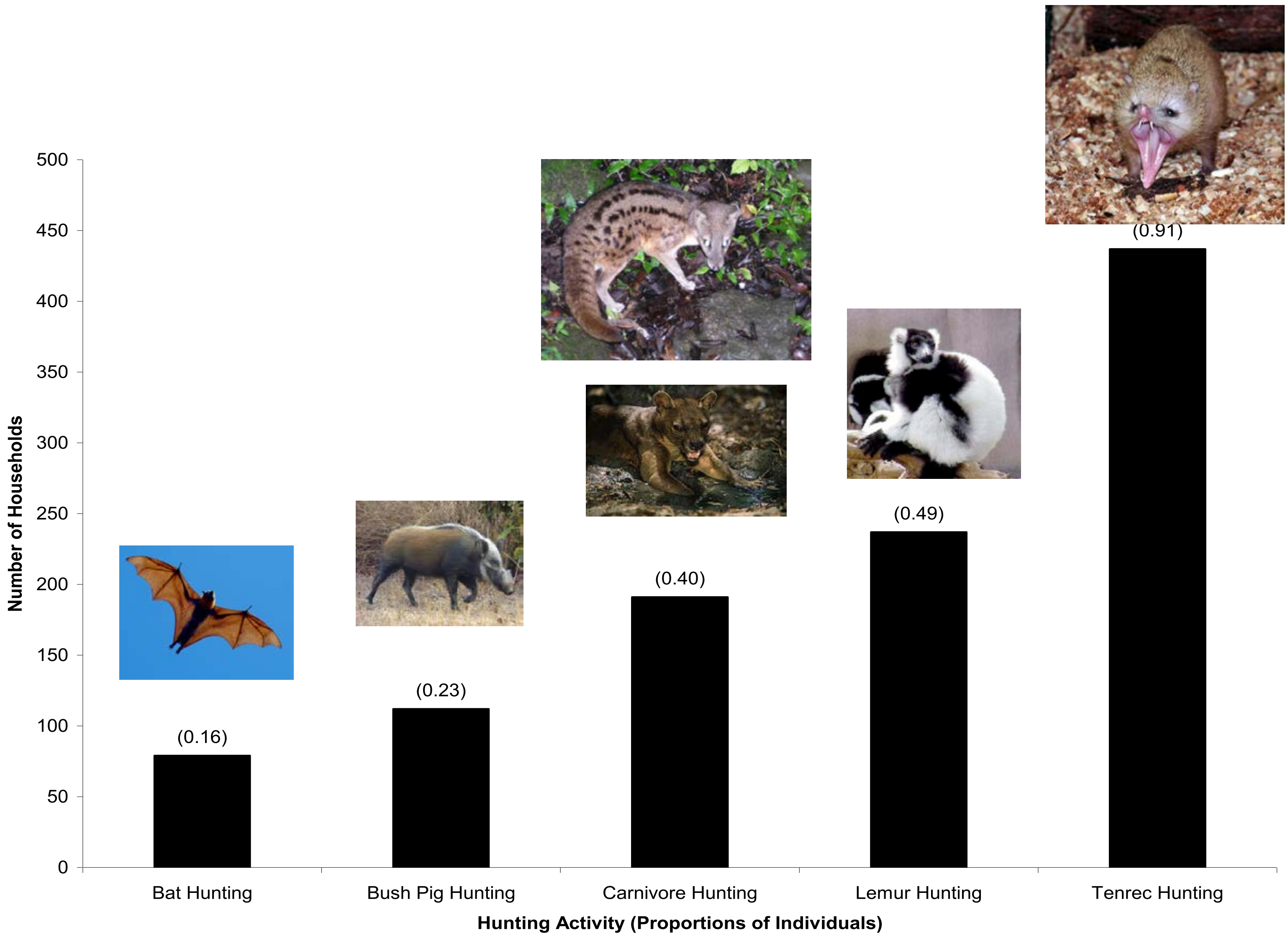
- *Collaborators:* Ryan Marsh, Elaina Marshalek, Samuel Evans, Lauren Whithey
- *Biodiversity, Health and Livelihoods Team:* Justin Brashares, Lia Fernald, Louise Fortmann, Claire Kremen, Katie Fiorella, Chris Golden
- *NSF Funding:* GEO-115057, CNH: Interactive Dynamics of Wildlife Populations, Human Health and Household Wealth in Rural Africa.

Biodiversity, Health & Livelihoods
Overview

- Global concern about biodiversity loss.
- Wildlife is the primary source of animal protein and income for more than 1 billion people (Milner-Guilland *et. al.* 2003).
- Open question: *How do we identify feasible strategies to improve peoples livelihoods and conserve biodiversity?*
- Research to date has focused on linkages between wealth, income and wildlife consumption.
- ***Today, focus on the missing link of health and explore how its inclusion impacts wildlife population dynamics and overall household well-being.***

Bushmeat & Development

Hunting in Madagascar



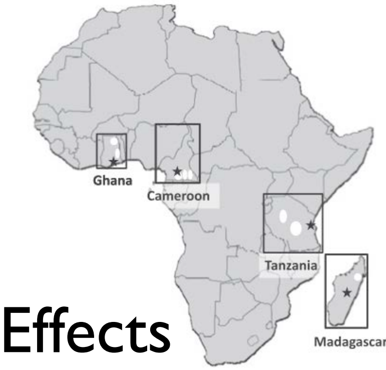
Bushmeat & Development
Economics

J. Brashares

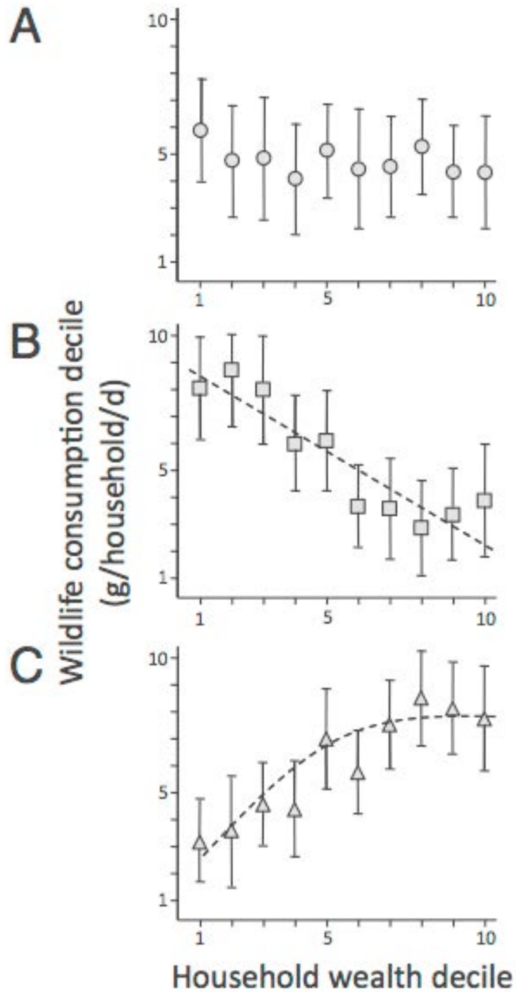
J. Brashares

The bushmeat trade is a local to global market that is valued at billions of dollars per year

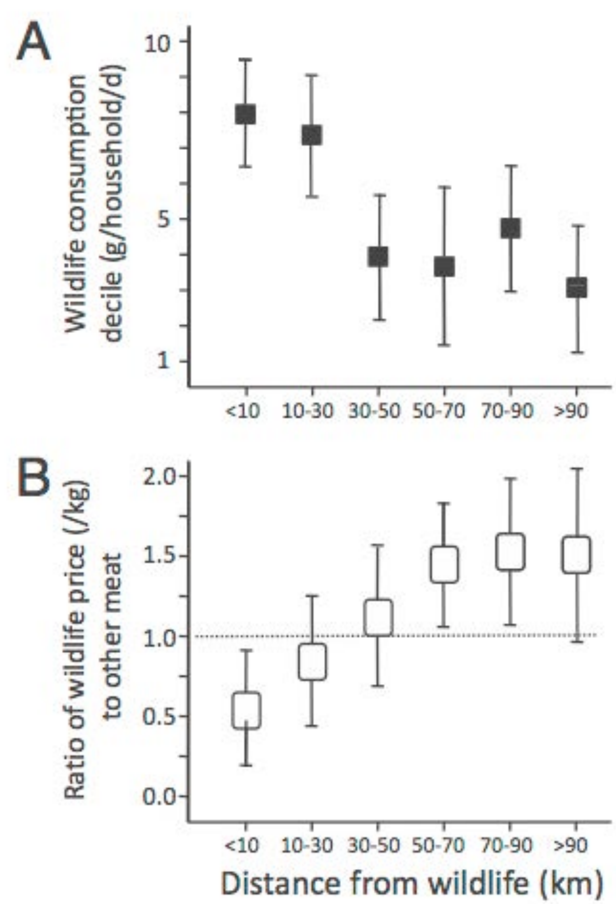
Bushmeat & Development
Economics



Wildlife Consumption & Wealth



Distance to Wildlife Effects



Economic and geographic drivers of wildlife consumption in rural Africa

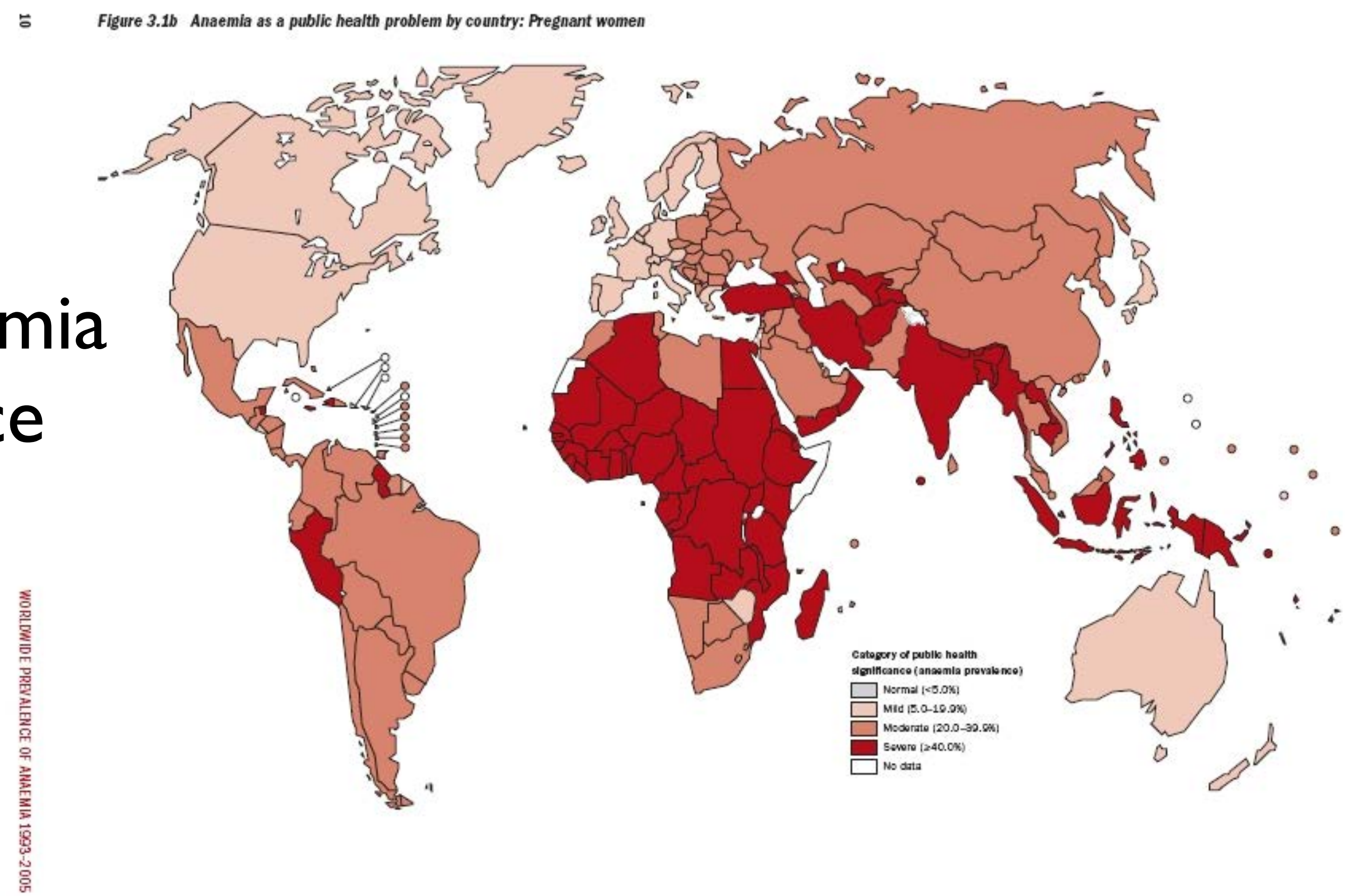
Justin S. Brashares[a,b,1], Christopher D. Golden[a], Karen Z. Weinbaum[a], Christopher B. Barrett[c], and Grace V. Okello[b]

www.pnas.org/cgi/doi/10.1073/pnas.1011526108

Bushmeat & Development

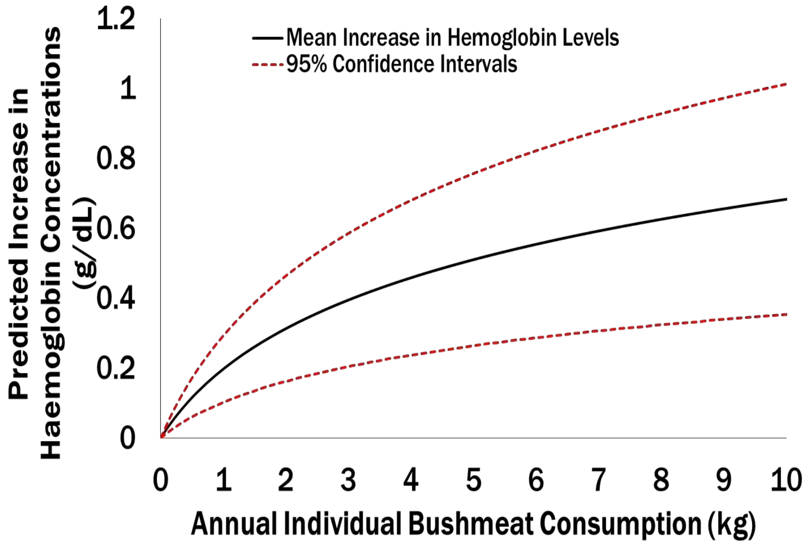
Health

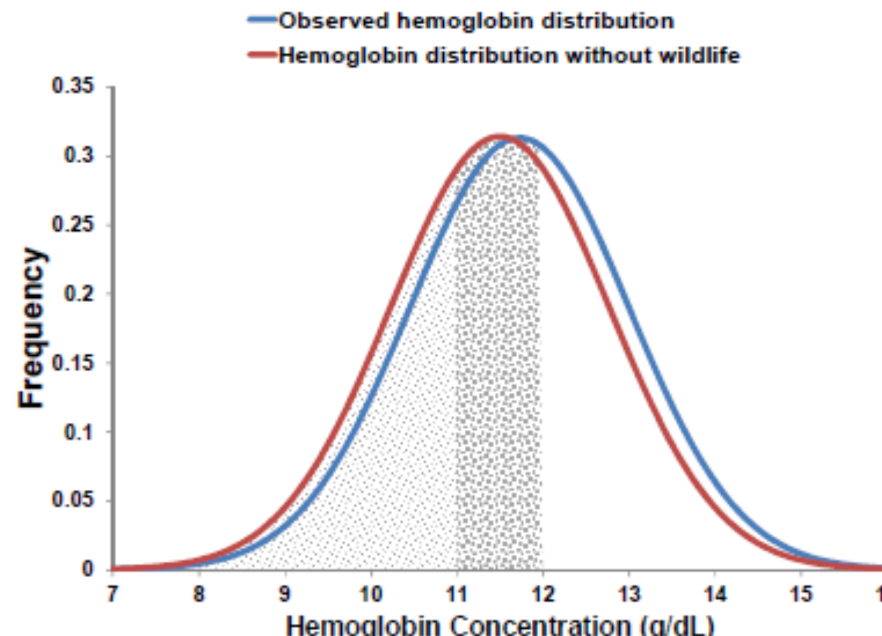
Global Anemia Prevalence



Bushmeat & Development

Impact of Bushmeat on Hemoglobin





Bushmeat could contribute app. 60-80% of what iron supplements accomplish

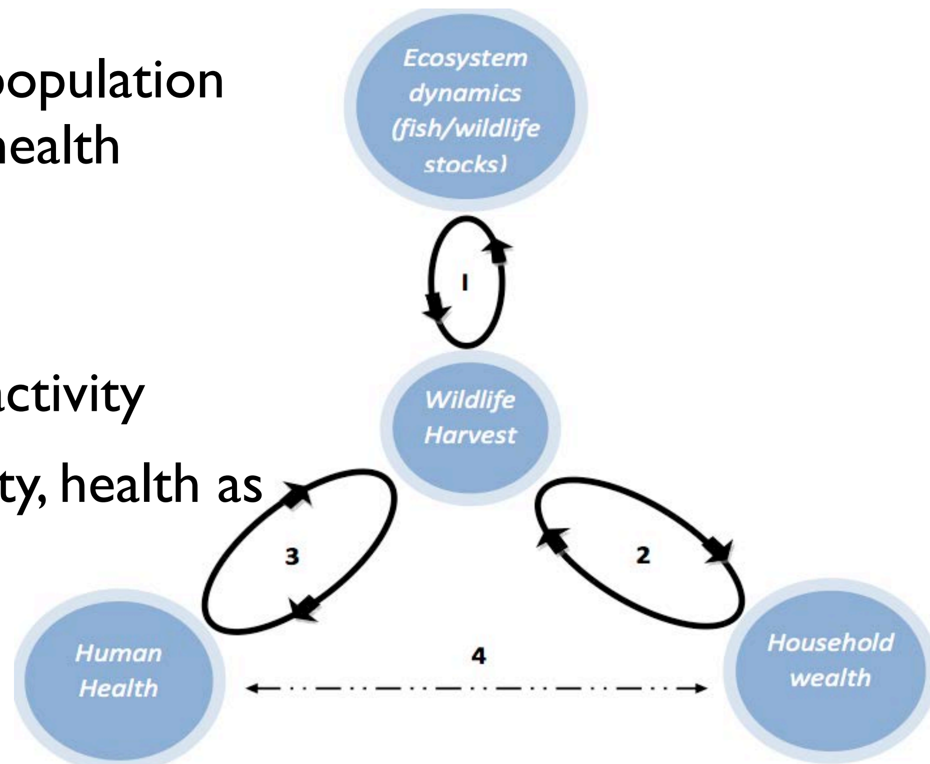
If access to bushmeat is lost, there will be a 30% increase in the incidence of anemia

C. Golden - Madagascar

Biodiversity, Health & Livelihoods
Guiding Question

How does the inclusion of health in household economic models impact wildlife population dynamics and overall household well-being?

- focus on time to collapse of wildlife population under different assumptions of how health status impacts labor availability:
  - reduces total labor
  - reduces total labor & agriculture activity
- track household labor allocation, utility, health as well as wildlife populations



Model
Big Picture

- Track utility and nutritional status of a "representative" subsistence household in a developing country.
- In each time period, households allocates labor to hunting and agriculture so as to maximize utility in that period *(not forward looking)*.
- Nutritional status determines total amount of labor available and is updated period to period.
- Wildlife population follows logistic growth with off take determined by hunting activity.
- Human population growing through time.
- Wildlife population *goes extinct* when population *falls below 20% of carrying capacity.*

Model
Key Variables

U_t - Utility of "representative" household at time t

G_t - Wild game population at time t

N_t - Nutritional status of household at time t

P_t - Total population at time t

Model
Utility Function

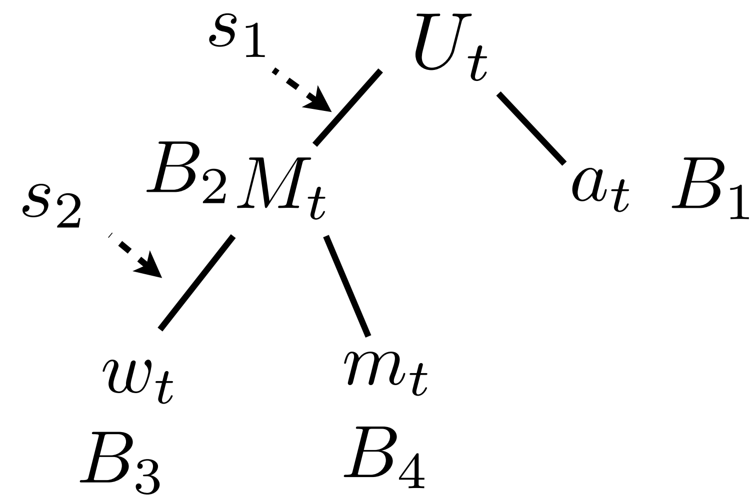
Household consume three goods: agriculture products (a), wild meat (w), and market meat (m)

$$U_t = (B_1 a_t^{\frac{s_1 - 1}{s_1}} + B_2 M_t^{\frac{s_1 - 1}{s_1}})^{\frac{s_1}{s_1 - 1}}$$

where $M_t = (B_3 w_t^{\frac{s_2 - 1}{s_2}} + B_4 m_t^{\frac{s_2 - 1}{s_2}})^{\frac{s_2}{s_2 - 1}}$

s_i - elasticity of substitution

B_i - budget share



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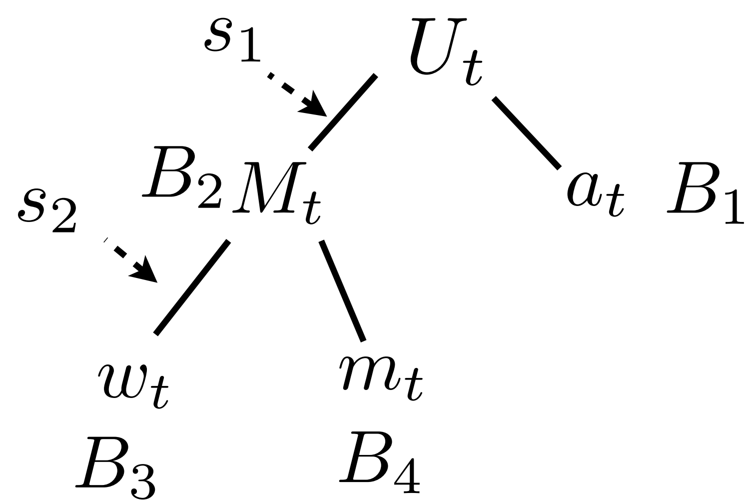

$$\begin{aligned} B_1 &= 0.8 \\ B_2 &= 0.2 \\ B_4 &= 0.5 \\ B_3 &= 0.5 \end{aligned} \qquad \begin{aligned} s_1 &= 1.1 \\ s_2 &= 1.1 \end{aligned}$$

Model

Constraints

- Crop production: $A = Y l_f^{\gamma}$
- Hunting: $H = Q G_t l_g$
- Budget: $R - C \geq 0$
- Labor: *Discuss Later*

where $R = p_a A + p_w H$ $\quad$ Q - catch per unit effort

$C = p_a a + p_w w + p_m m$

$$Y = 1 \quad Q = 0.0003 \quad \gamma = 0.5$$
$$p_a = 1 \quad p_w = 5 \quad p_m = 5$$

Model
State Equations I

- Utility - no updating since it maximized in each period.

- Population: $P_{t+1} = r_p P_t$

- Game:

$$\underbrace{}_{}G_{t+1} = \underset{\text{growth rate}}{r}G_t(1 + G_t/\underset{\text{carrying capacity}}{K_G}) - QG_t l_g P + G_t$$

Note: Game extinct when it reaches 20% of carrying capacity

$$\boxed{r_p = 1.03 \quad r = 0.5 \quad K_G = 500}$$

Model
State Equations II

- Energy status (ES) in a time period t

$$ES_t = \frac{e_m(w+m) + e_f a}{E_f l_f + E_g l_g}$$

- Nutrition:

If $\mathrm{ES_t} \geq 1$: $N_{t+1} = N_t + (1 - N_t)/dN$

If $\mathrm{ES_t} \leq 1$: $N_{t+1} = N_t - N_t/dN$

If $\mathrm{ES_t} \leq \mathrm{ES_{min}}$: $N_{t+1} = N_{\mathrm{min}}$

- Labor dependence on nutritional status

I. No impact: $l_f + l_g = l_{\mathrm{total}}$

II. Impacts total labor: $l_f + l_g = N_t l_{\mathrm{total}}$

III. Impacts total labor & farm labor: $l_f + l_g = N_t l_{\mathrm{total}}$ If $N_t < N_c$ $l_f = 0$

Model

State Equations II

- Energy status (ES) in a time period t

$$ES_t = \frac{e_m(w+m) + e_f a}{E_f l_f + E_g l_g}$$

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If $ES_t \leq ES_{min}$: $N_{t+1} = N_{\text{min}}$

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III. Impacts total labor & farm labor: $l_f + l_g = N_t l_{\text{total}}$

If $N_t < N_c$, $l_f = 0$

$e_m = 1.65$

$e_f = 1.00$

$E_f = 1.20$

$E_g = 1.00$

$dN = 10$

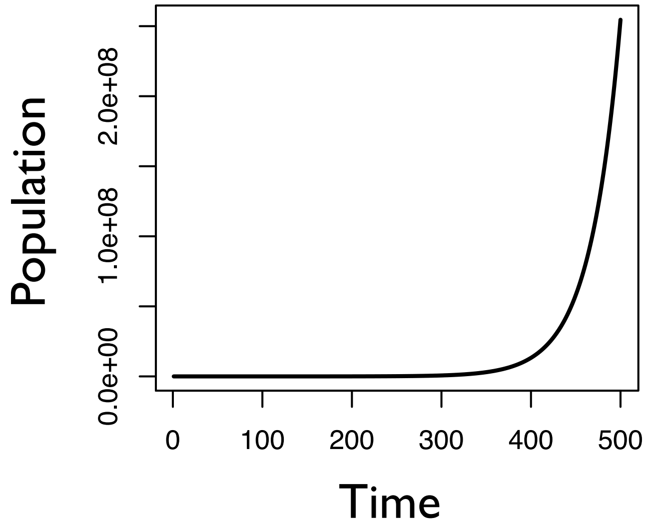
$N_{\text{min}} = 0.1$

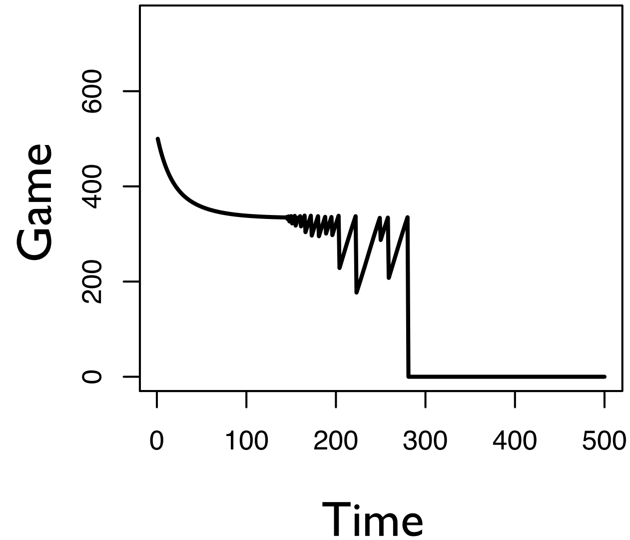
$l_{\text{total}} = 1$

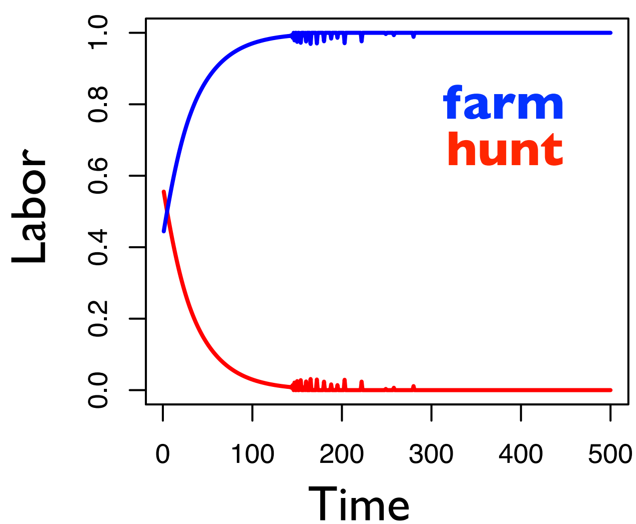
$N_c = 0.3$

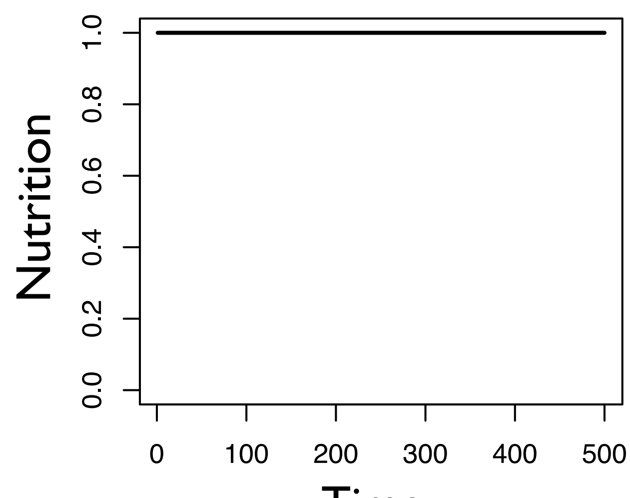
Results to Date

Base Case
(No Nutritional Impact on Labor)





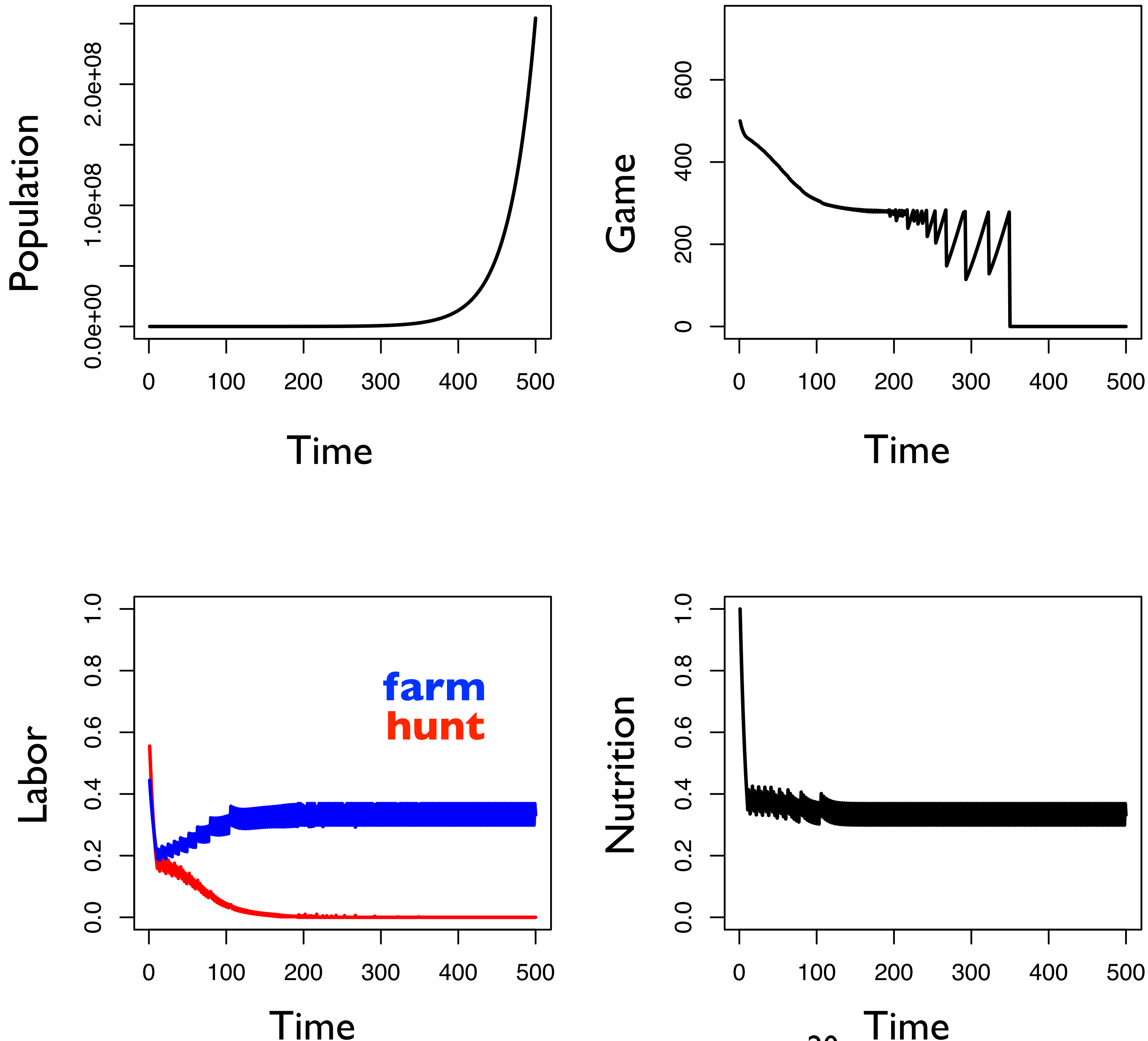




- Game population crashes in ~ 300 time steps.
- Labor allocation shifts to farming due to higher utility gained from farming and lack of game.

Solved used GAMS

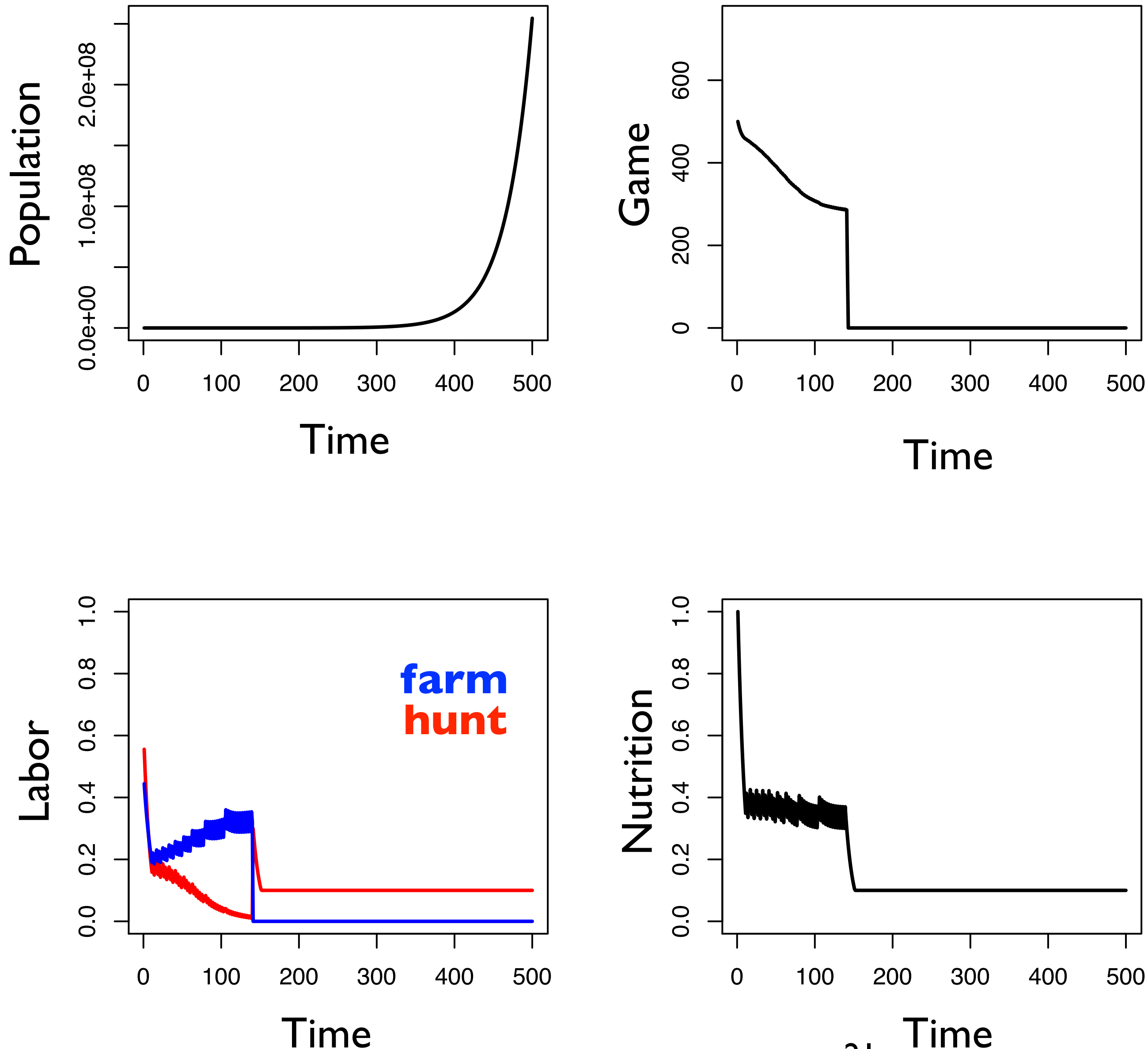
Nutrition Impacts Total Labor



- Game population crashes in ~ 350 time steps.
- Linking nutritional status to labor allocation increase time to extinction.
- No qualitative change in labor allocation between hunting and farmer.

Solved used GAMS

Nutrition impacts total labor & critical threshold for farming



- Game population crashes in ~ 150 time steps.
- Loss of ability to farm leads to rapid game extinction.

Solved used GAMS

Preliminary Conclusions

- Incorporation of nutritional status and linking it to labor availability and allocation can dramatically change the time to extinction of wild game species.
- Results highly depending on assumption concerning functional relationships and parameter values.

Next Steps (*Lots more work*)

- Get good parameter values
- Track multiple households
- Incorporate household savings
- Add weather shocks
- Incorporate different preferences for wild versus market meat
- Make it forward looking (*stochastic dynamic programming*)

Thank You!
Questions?