

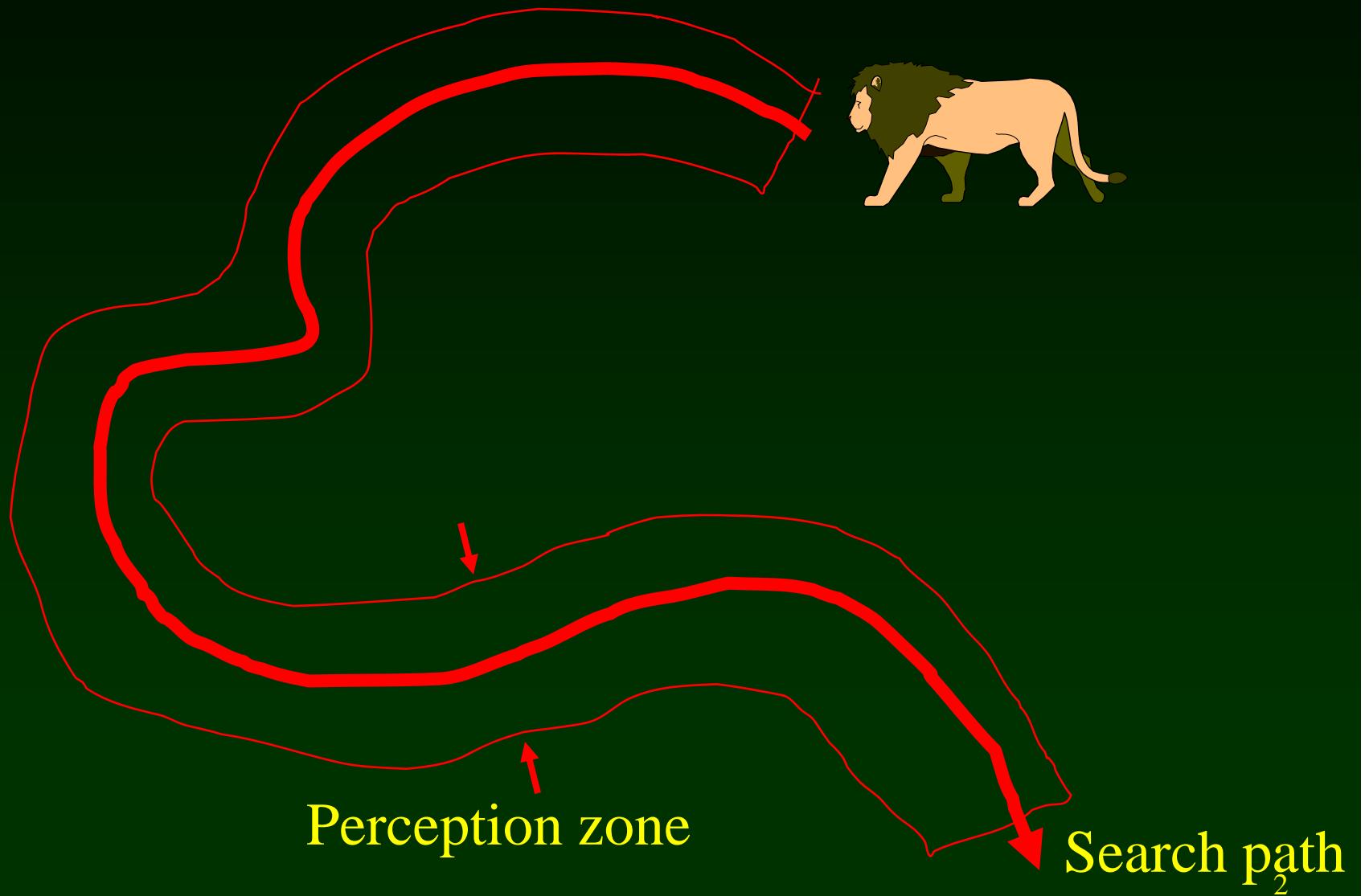
SOCIAL & SPATIAL CONSTRAINTS ON PREDATOR-PREY DYNAMICS



1

Photo: John Fryxell

Imagine a lion that hasn't met Mark Lewis:



functional response

$$\Psi(N) = \frac{a \cdot N}{1 + a \cdot (h_1 + h_2) \cdot N}$$

a = search path width (0.4 km) x travel velocity (10 km/day)
x probability of success (0.29) = 1.16 km²/day

h_1 = time/attack (0.013 day) x attacks/capture (3.4)
= 0.045 day for lions hunting wildebeest

h_2 = carcass mass (85 kg) x digest time/mass (0.017 day/kg)
= 1.422 days for lions hunting wildebeest

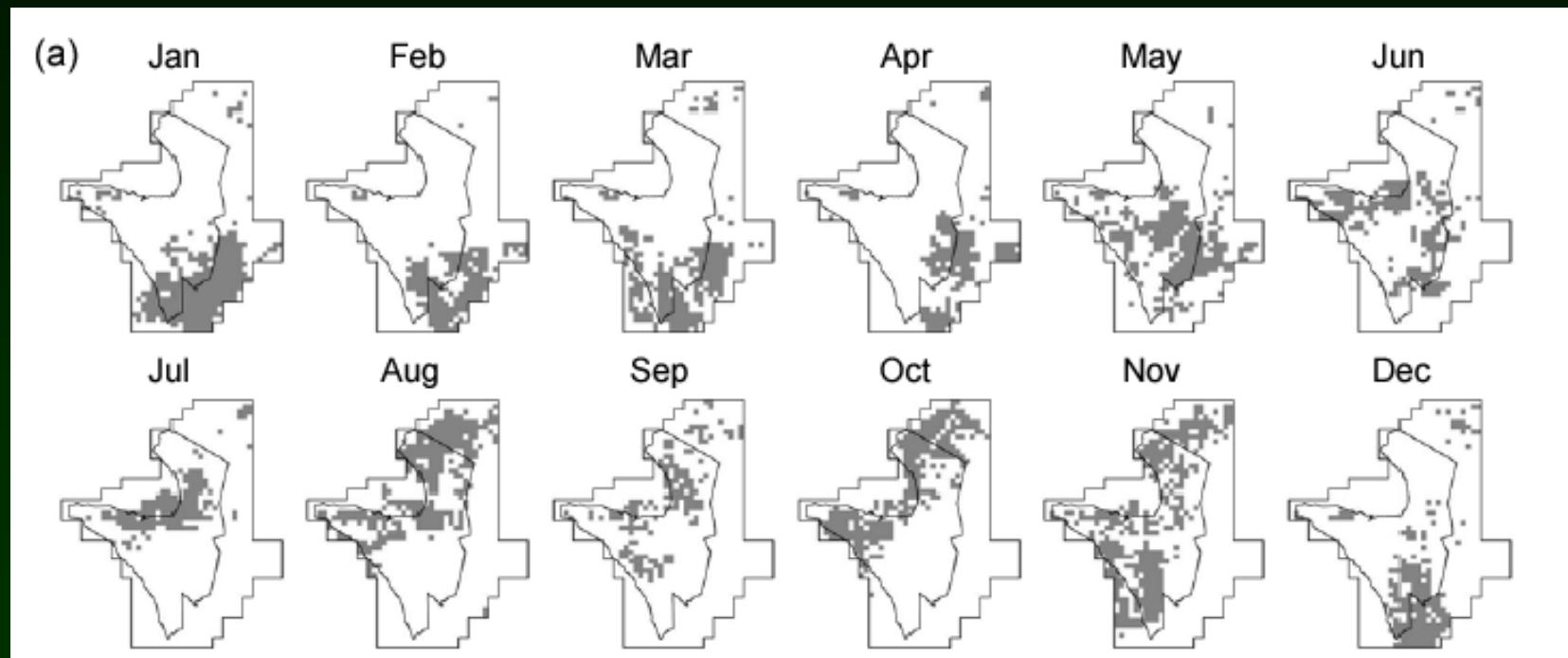
Prey are both highly aggregated
and highly mobile



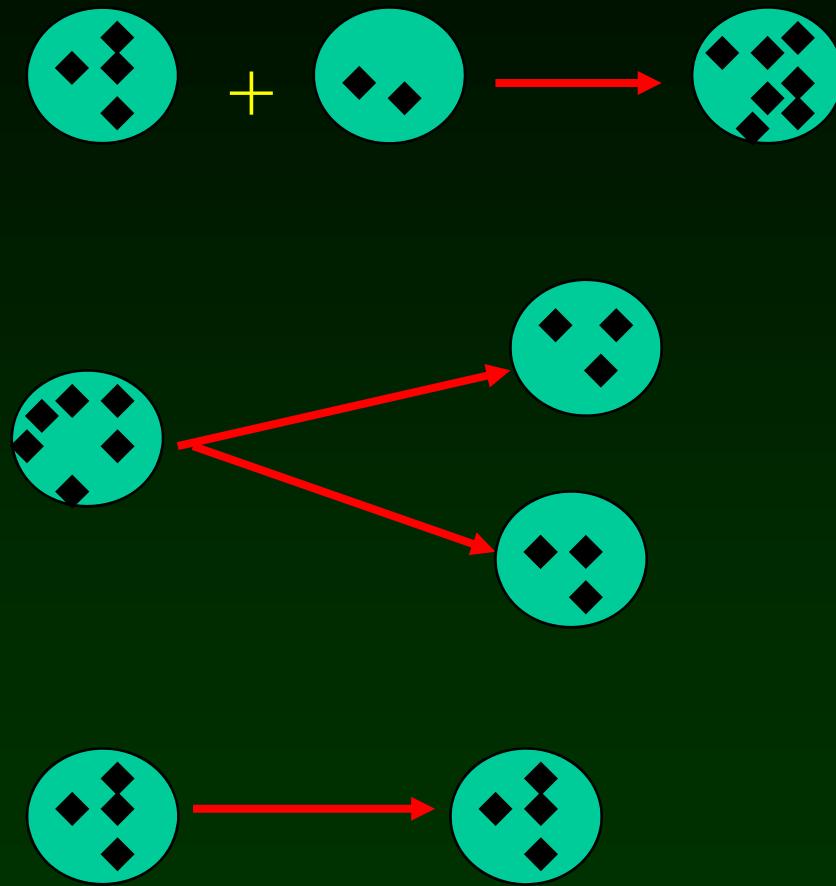
4

Photo: Tony Sinclair

Migration across seasons combined with nomadism within seasons in the Serengeti wildebeest



Changes due to random fission and fusion events...



*Gueron and Levin (1995) The dynamics of group formation,
Math Biosci 128:243-264*

Fission

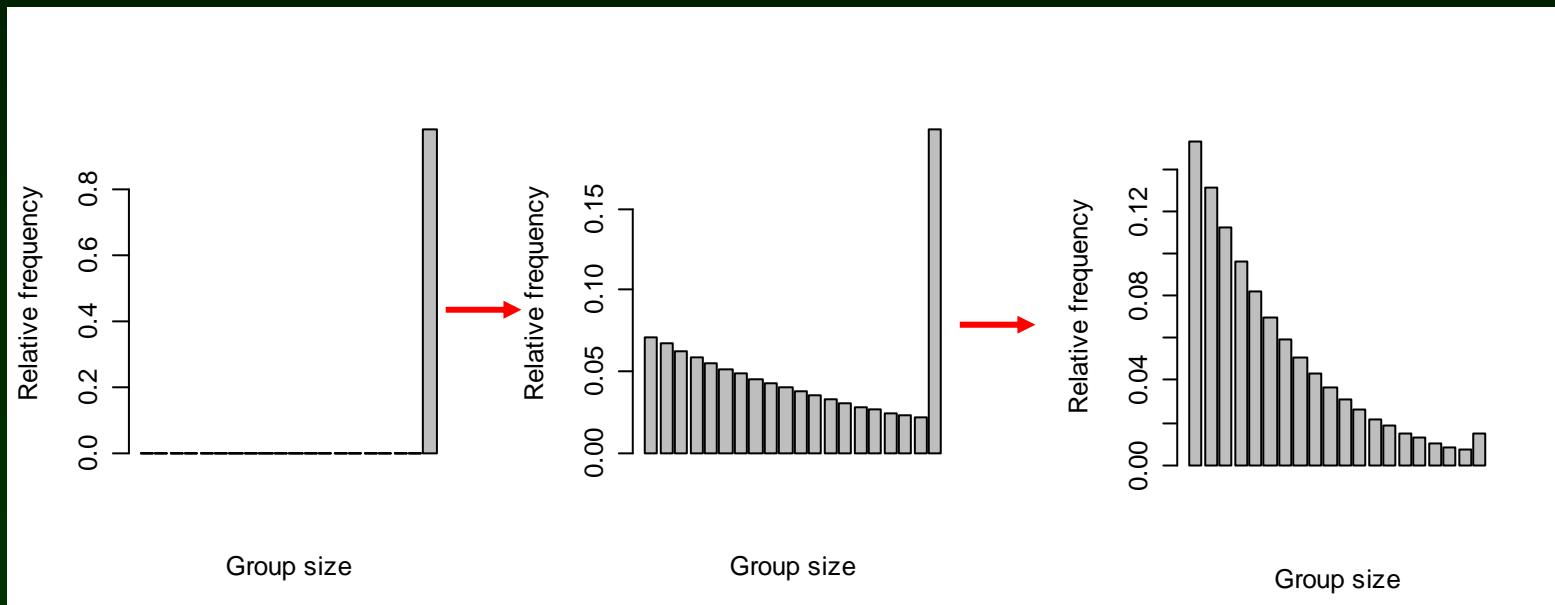
Fusion

Fusion

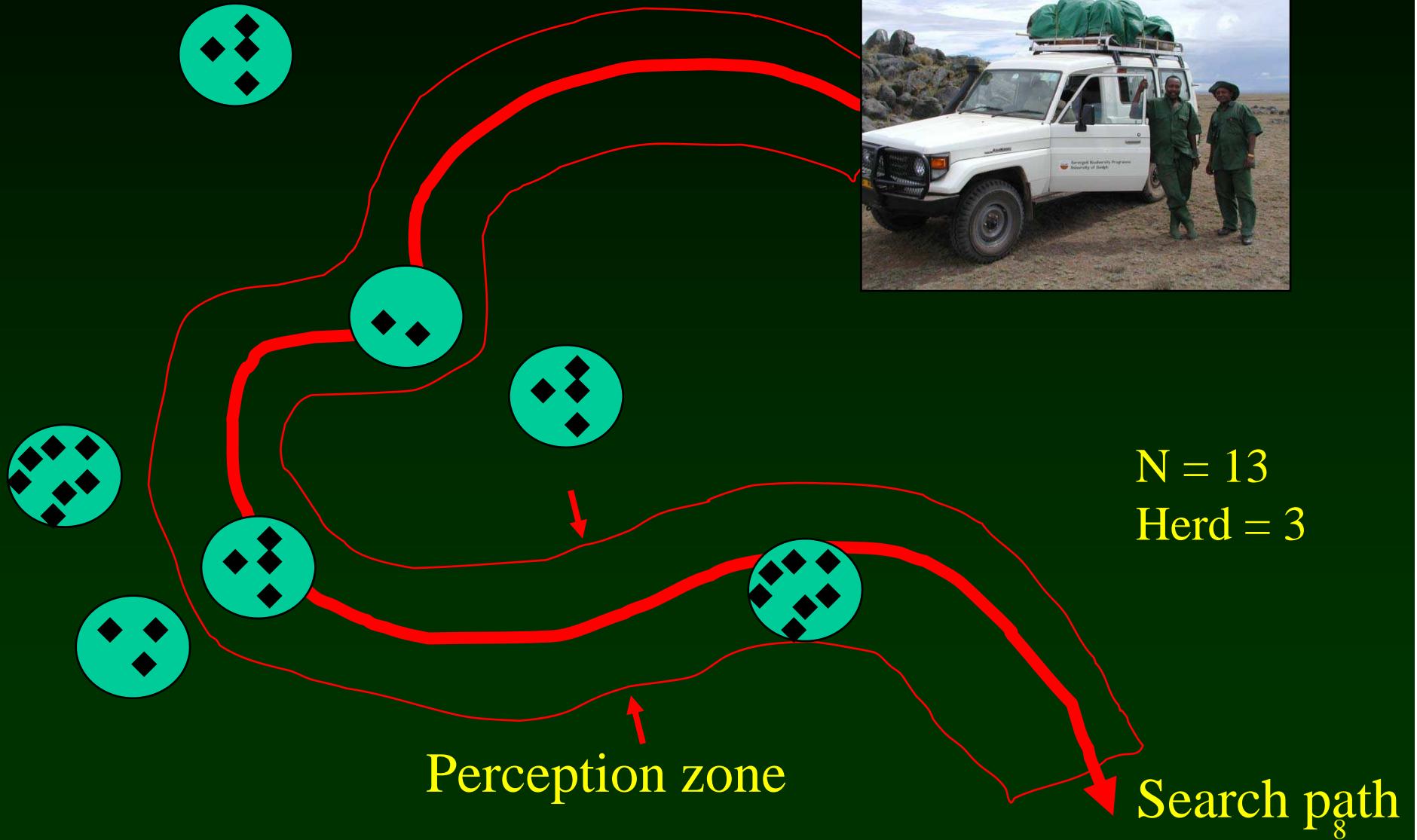
Fission

$$\frac{df(x)}{dt} = -\beta \cdot x \cdot f(x) - \alpha \cdot f(x) \cdot \int_0^{\infty} f(z) dz + \frac{\alpha}{2} \cdot \int_0^x f(y) \cdot f(x-y) dy + 2 \cdot \beta \cdot \int_x^{\infty} f(y) dy$$

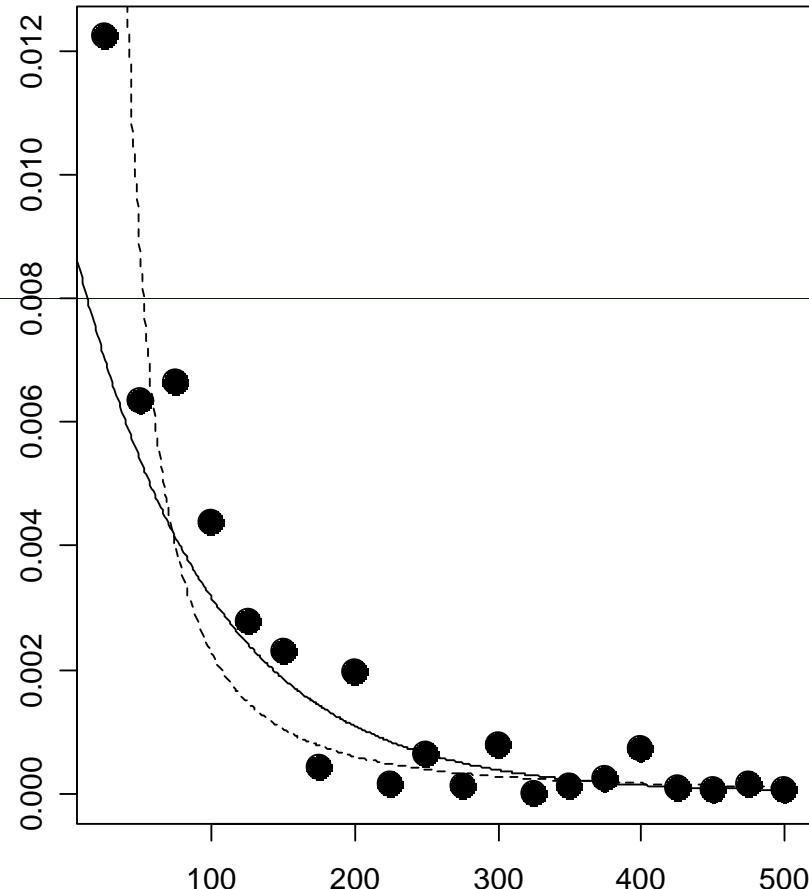
Gueron and Levin 1995

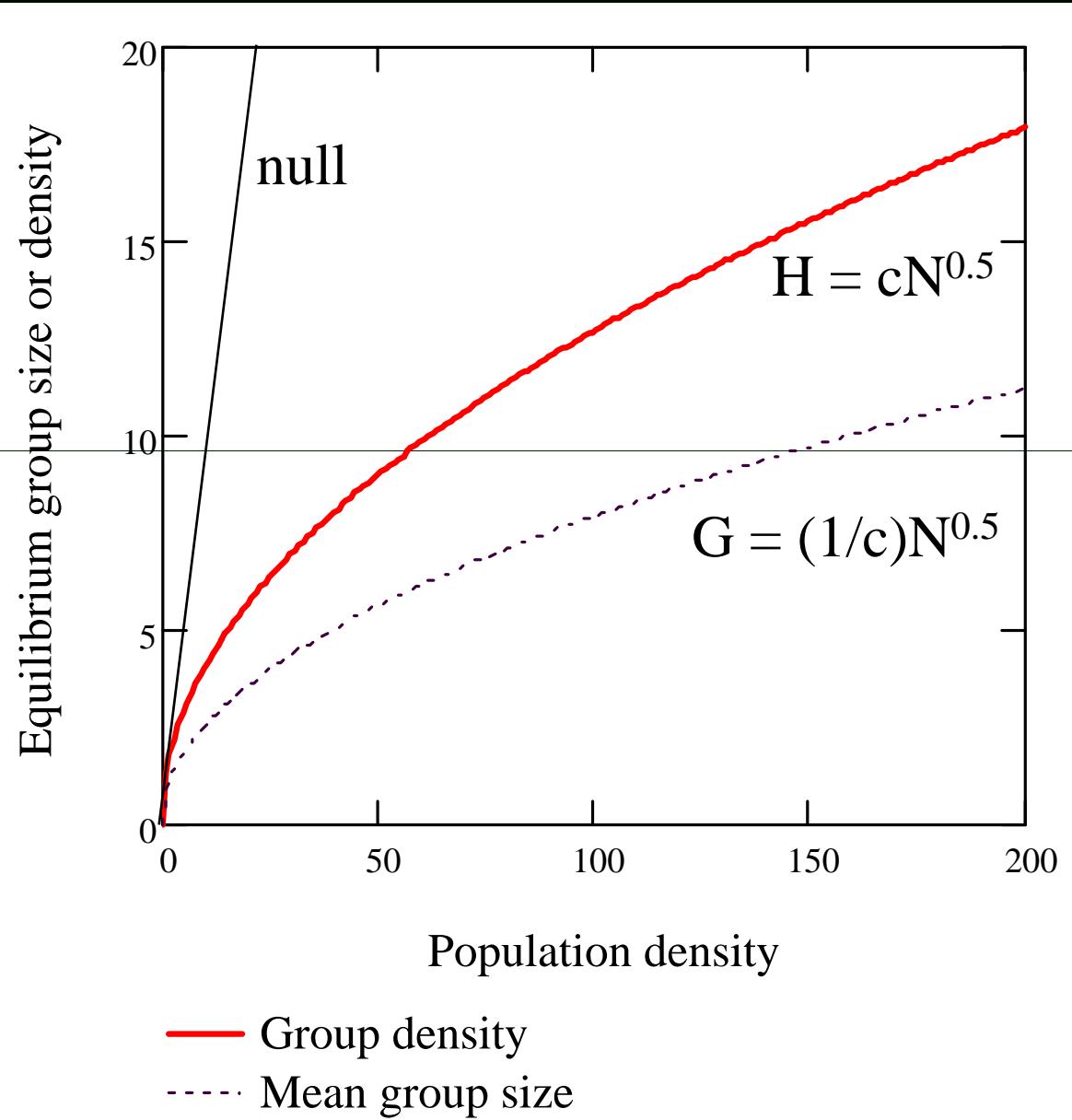


Estimating group vs population density

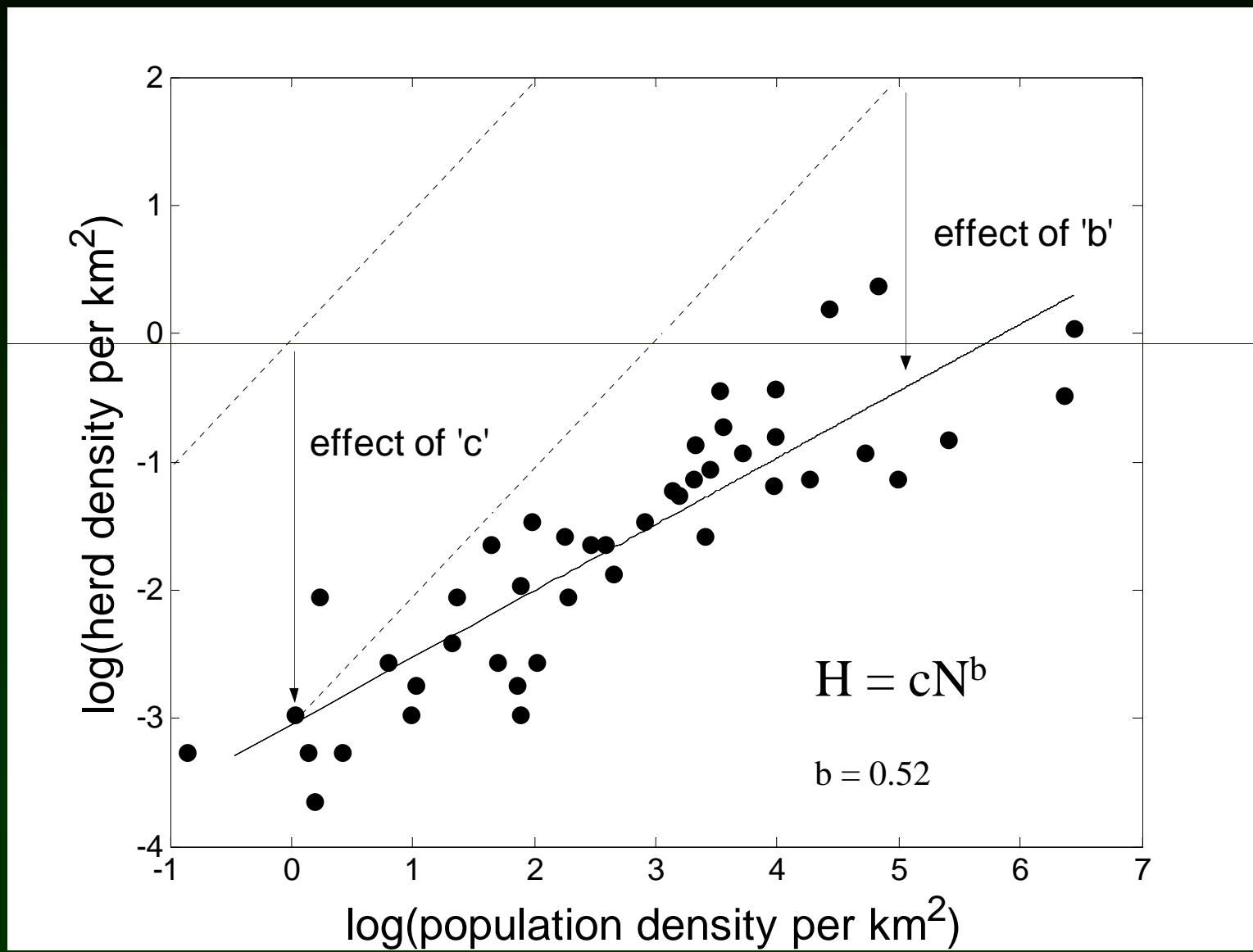


Wildebeest





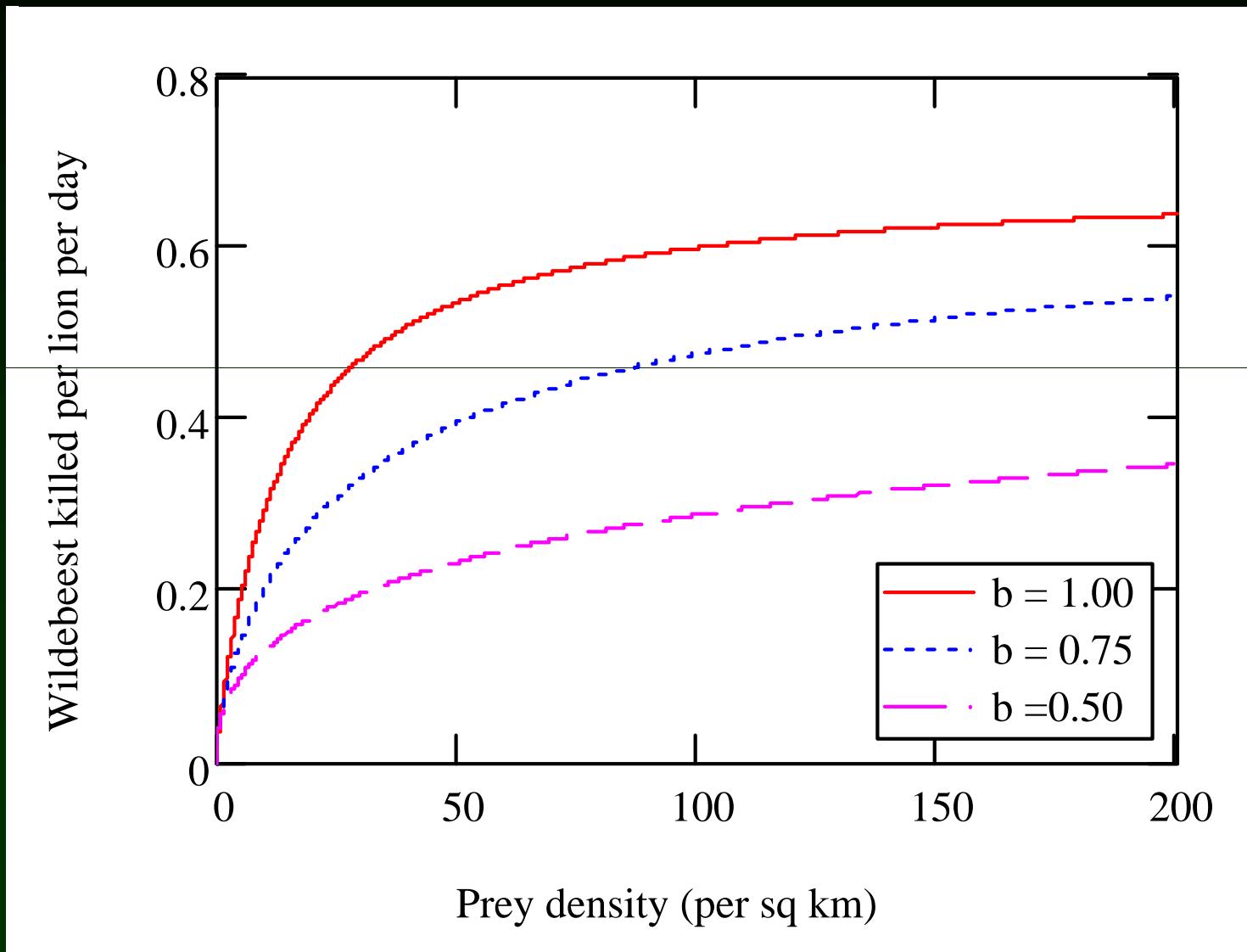
Wildebeest group density vs. population density



Consequences of prey grouping...

$$\Psi(N) = \frac{a \cdot c \cdot N^b}{1 + a \cdot (h_1 + h_2) \cdot c \cdot N^b}$$

reduced encounter rate

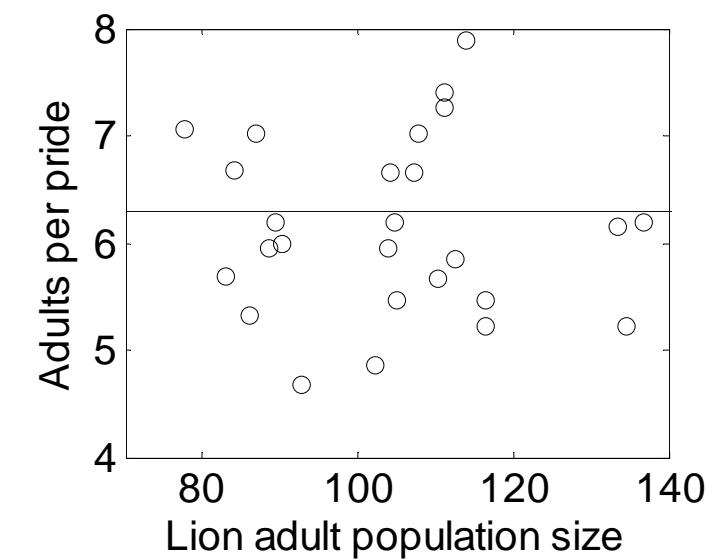
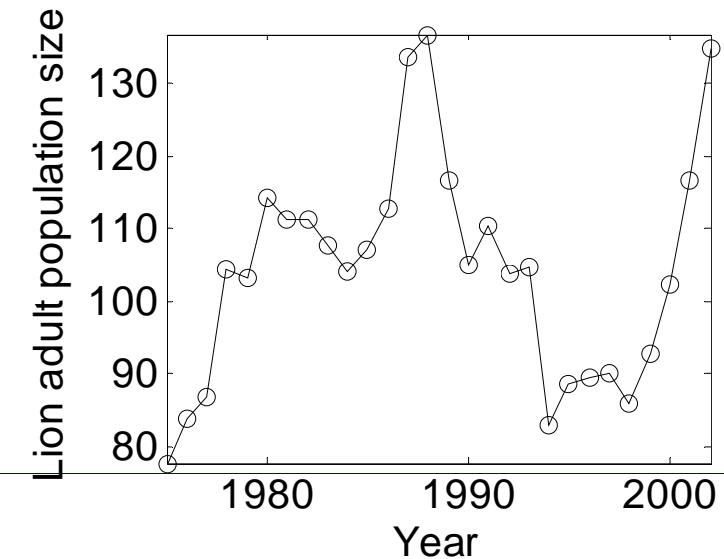


Lions are gregarious, forming prides



Photo: Craig Packer

Lions have
varied
considerably
in abundance
over time...



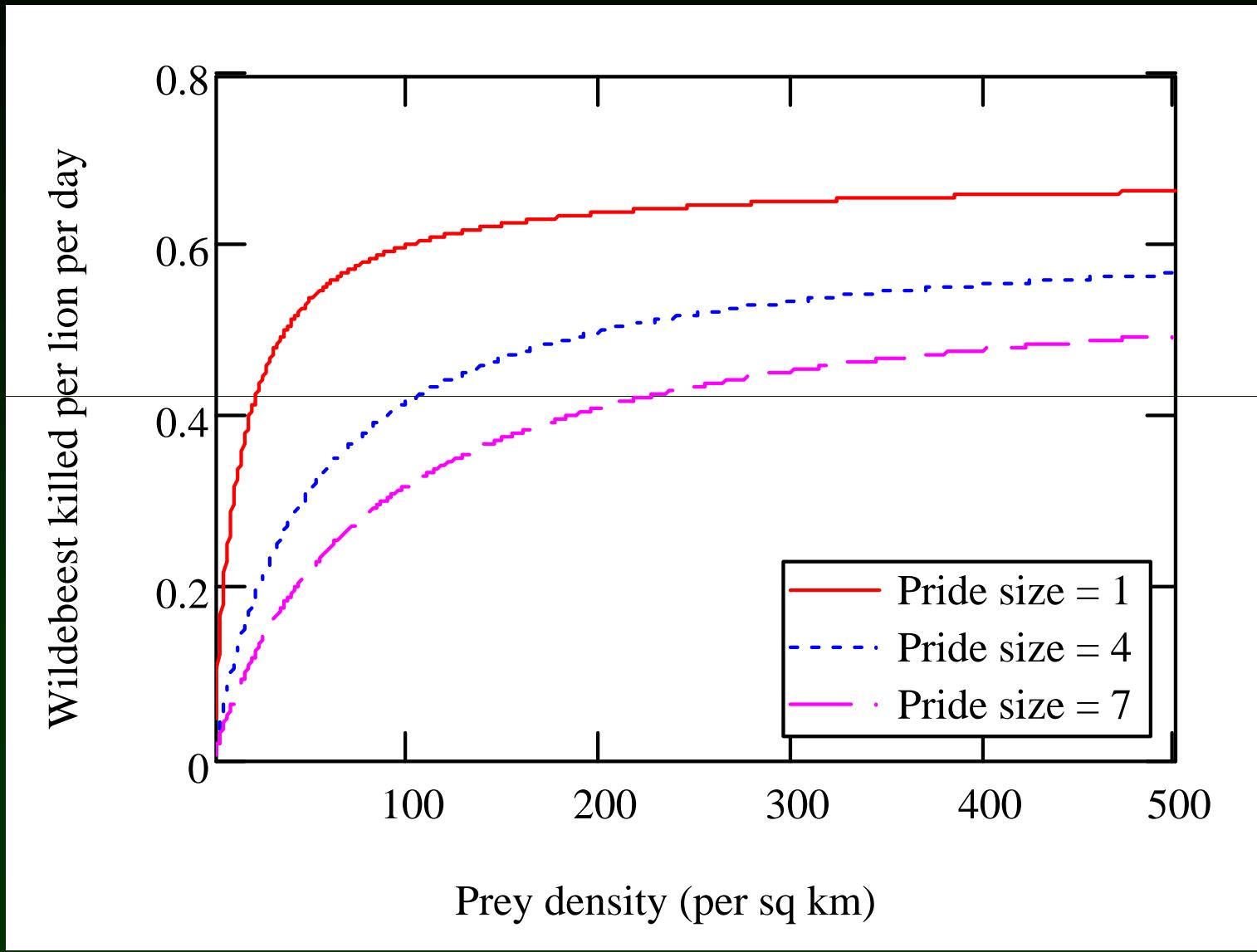
...but average group
size hasn't ($G = 6.3$)

Consequences of predator grouping

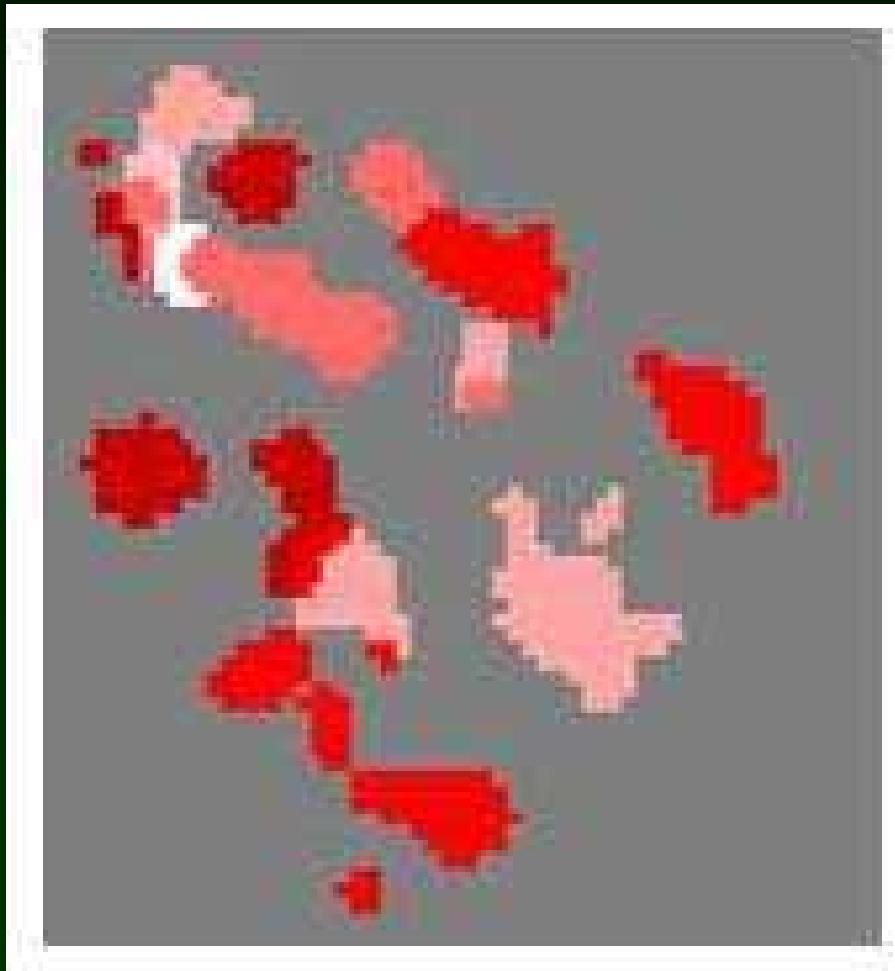
each prey must be shared with group

$$\Psi(N, G) = \left(\frac{1}{G} \right) \cdot \left[\frac{a \cdot N}{1 + a \cdot N \cdot \left(h_1 + \frac{h_2}{G} \right)} \right]$$

reduced handling time
per predator



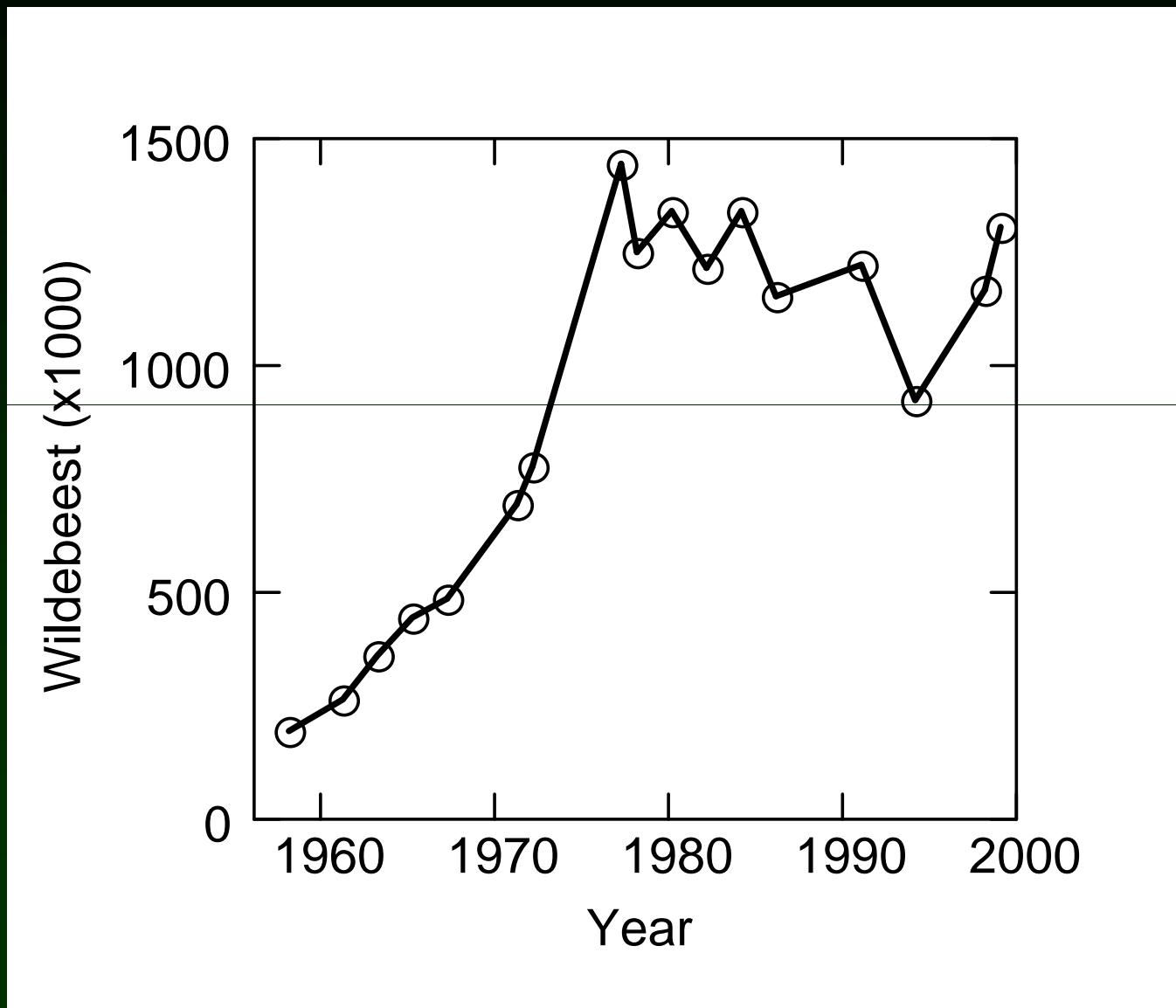
Lions must defend group territories against other prides, favoring formation of large groups, even though it may compromise foraging.

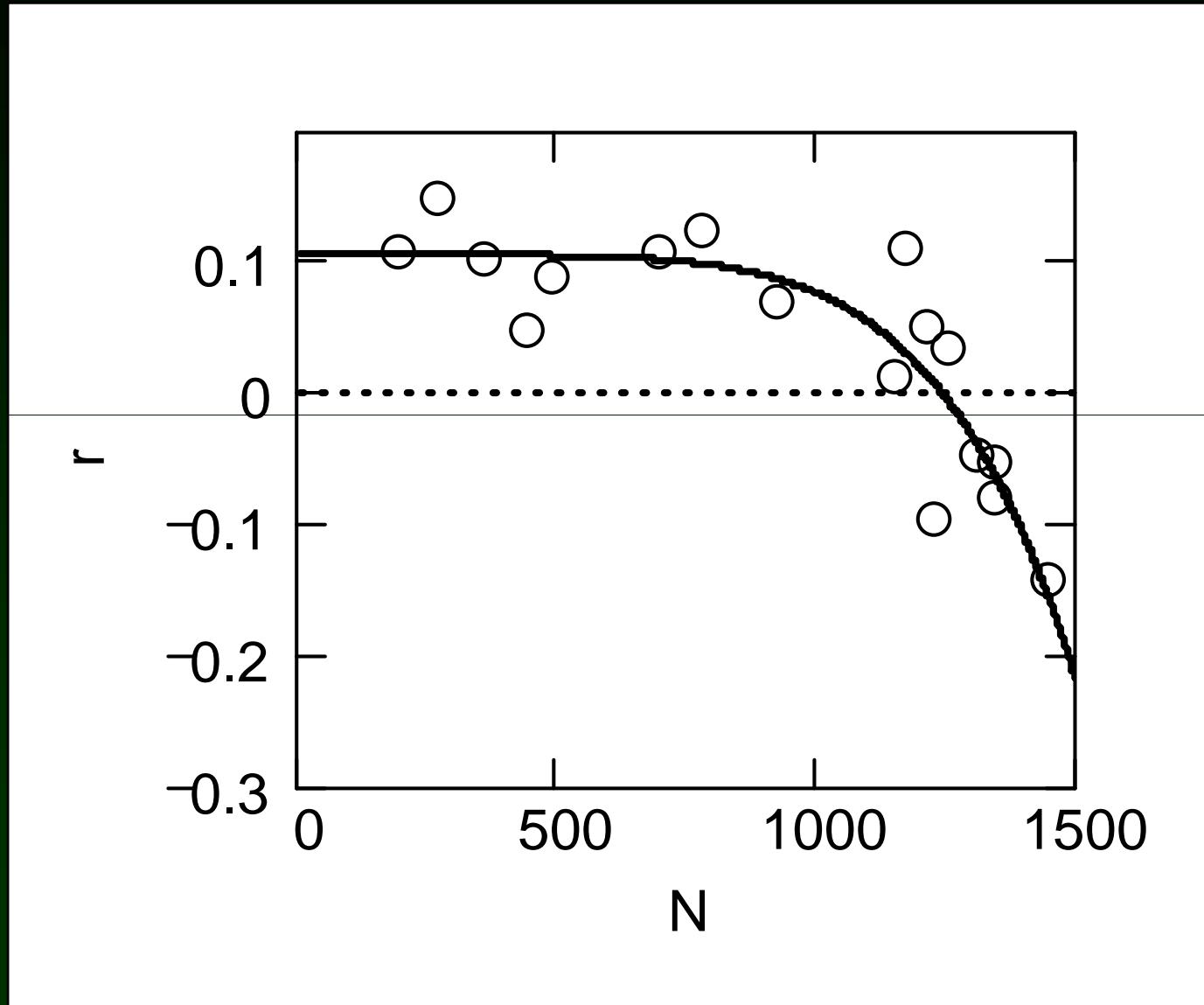


Mosser et al.
(in press) Ecol Lett

Topics

- Group formation and lion functional response
- Group formation and predator-prey dynamics



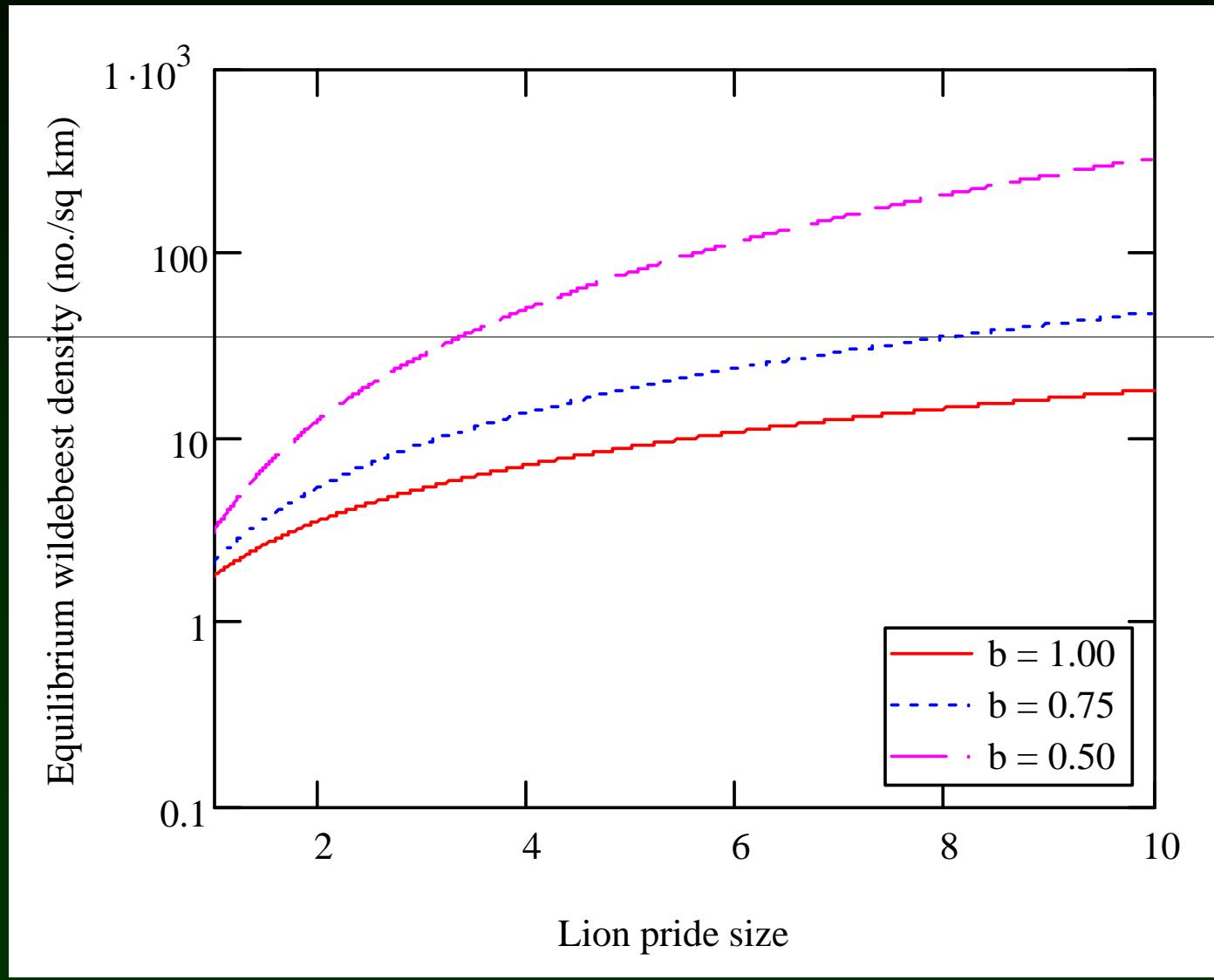


Dynamics of lion-wildebeest system:

$$\frac{d}{dt} N(t) = r_{\max} \cdot N(t) \cdot \left[1 - \left(\frac{N(t)}{K} \right)^{\theta} \right] - P(t) \cdot \Psi(N(t), G)$$

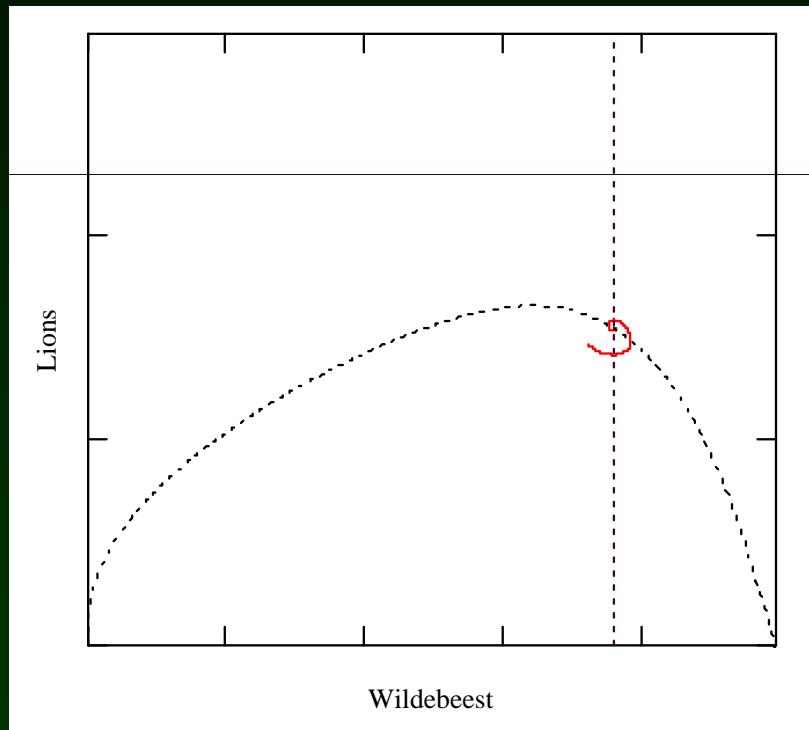
$$\frac{d}{dt} P(t) = P(t) \cdot (\varepsilon \cdot \Psi(N(t), G) - d)$$

Prey abundance required to sustain predators

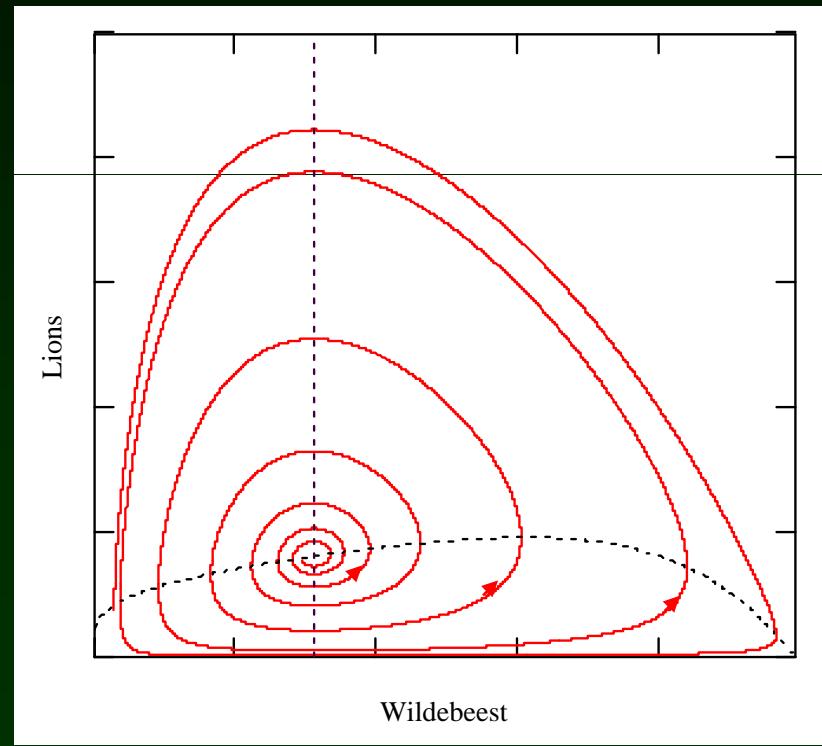


Prey grouping is stabilizing...

$b = 0.5$

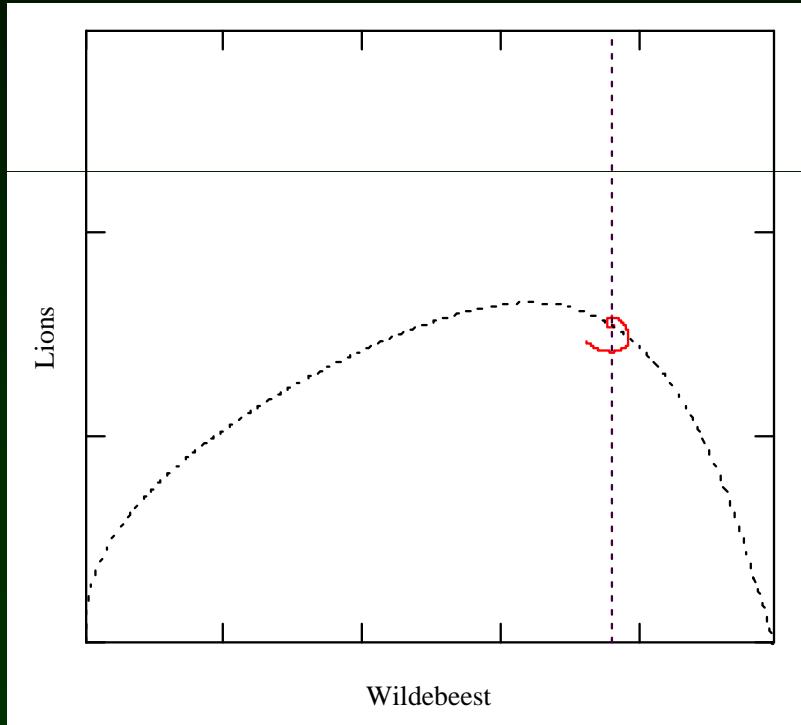


$b = 0.75$

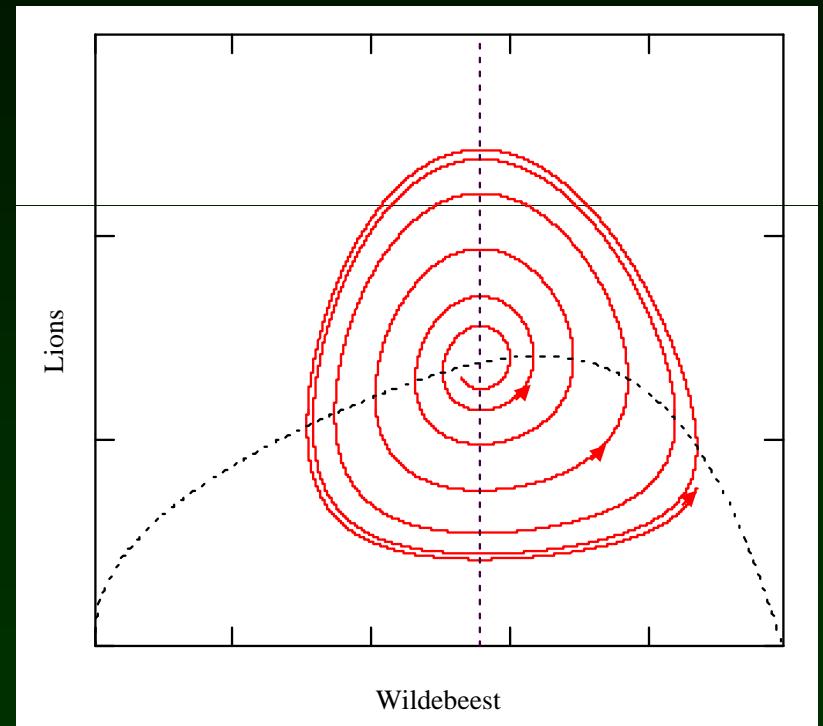


Predator grouping is stabilizing...

6.3 lions/pride



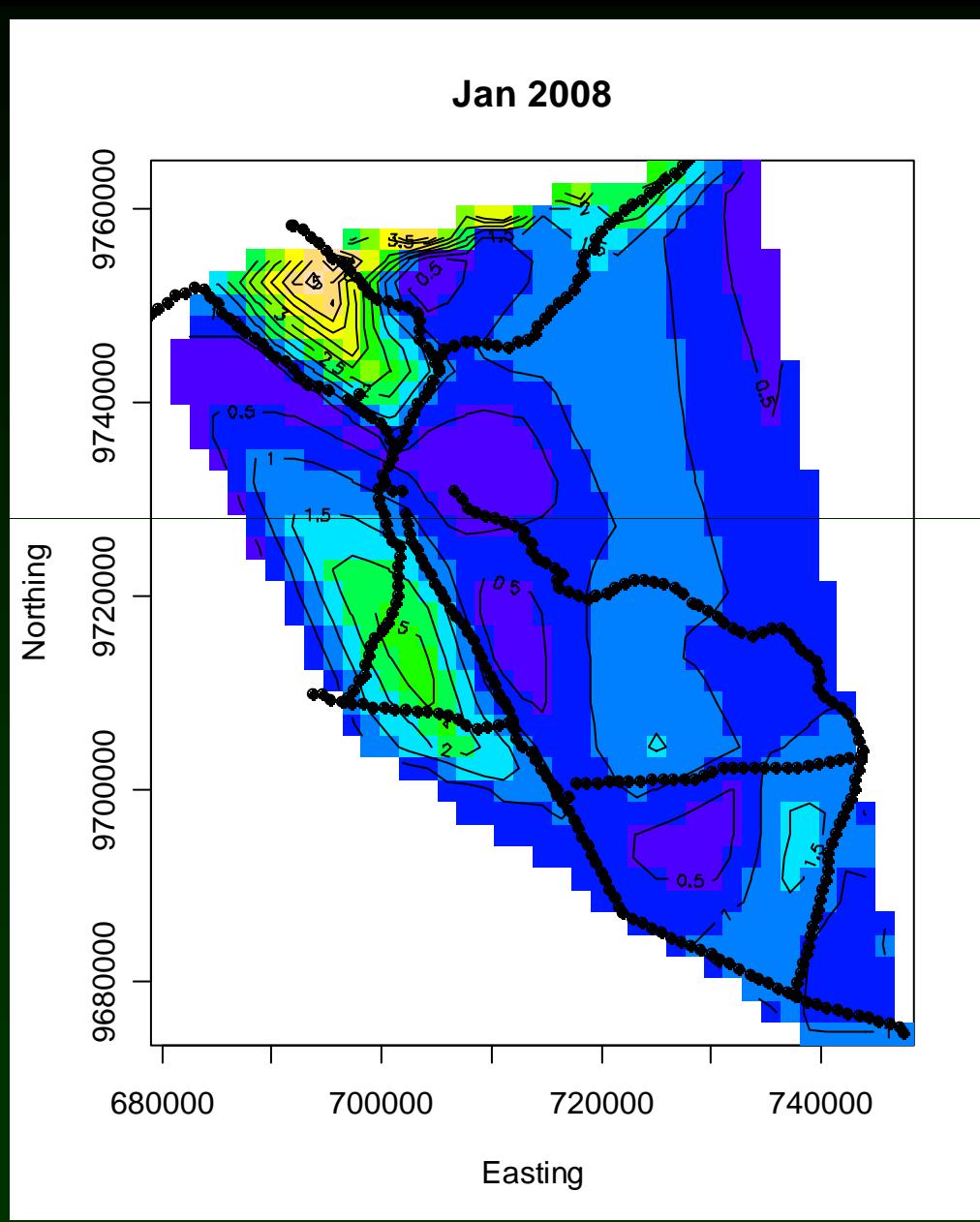
5.3 lions/pride

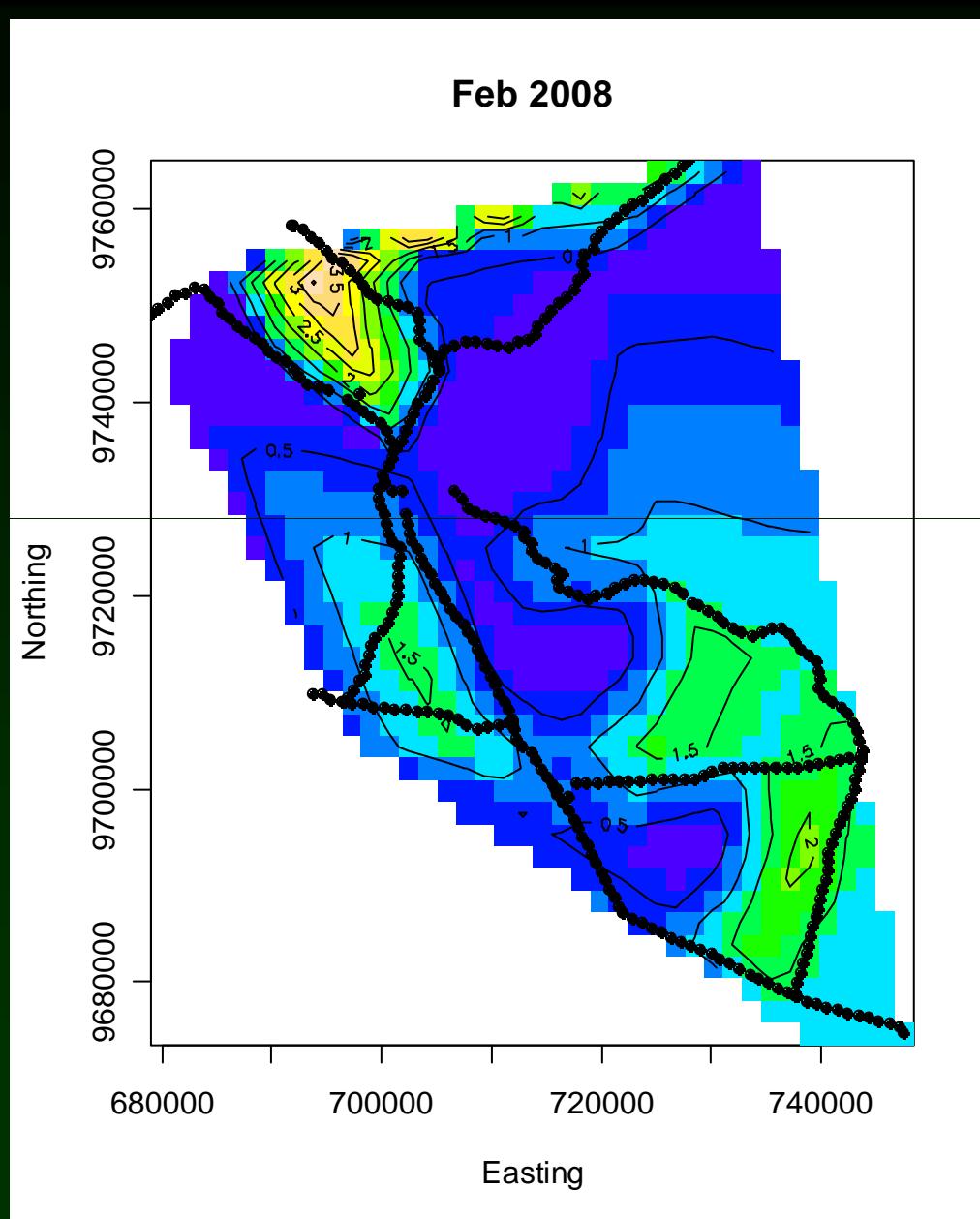


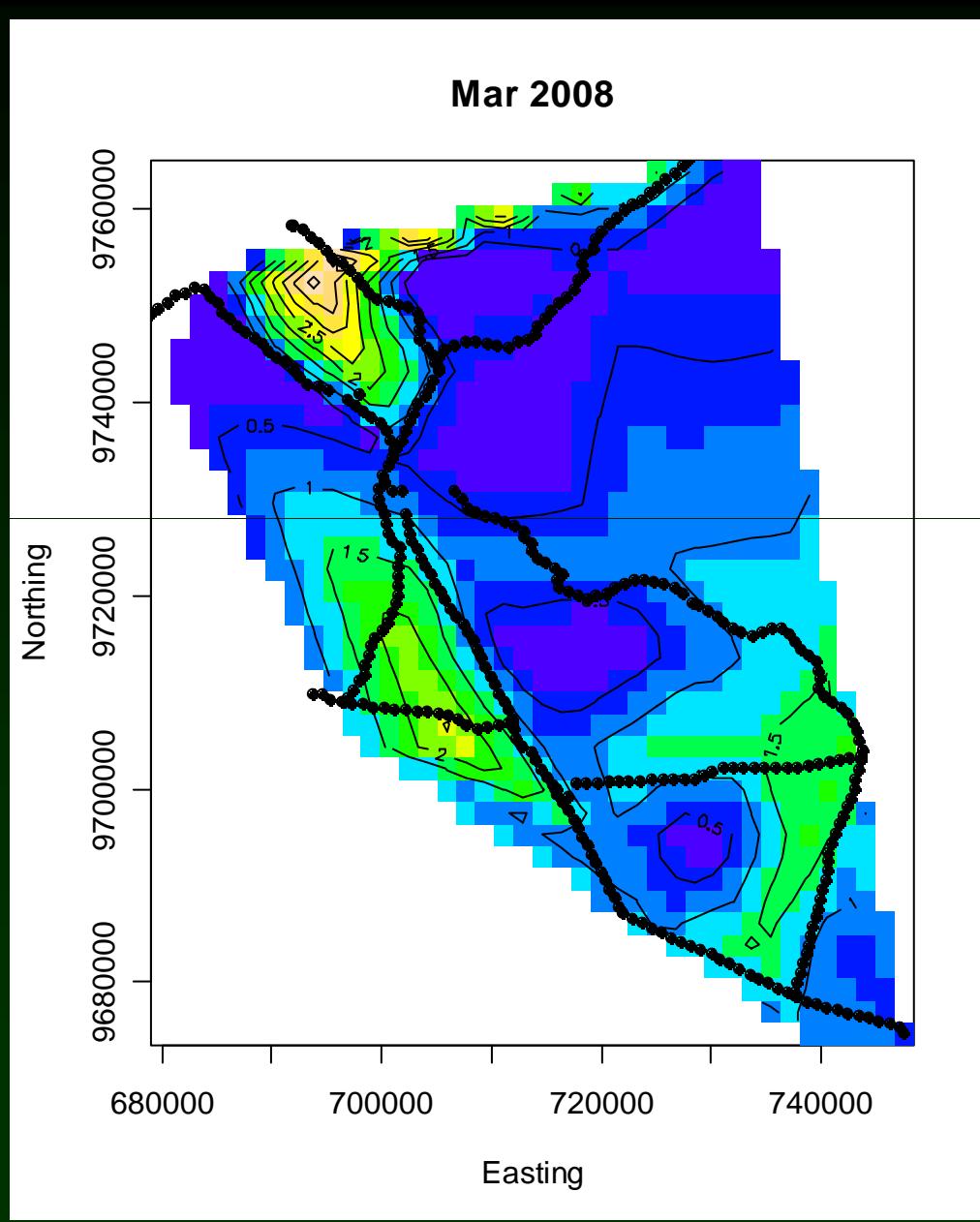
Hence, hunting of social predators could be destabilizing...

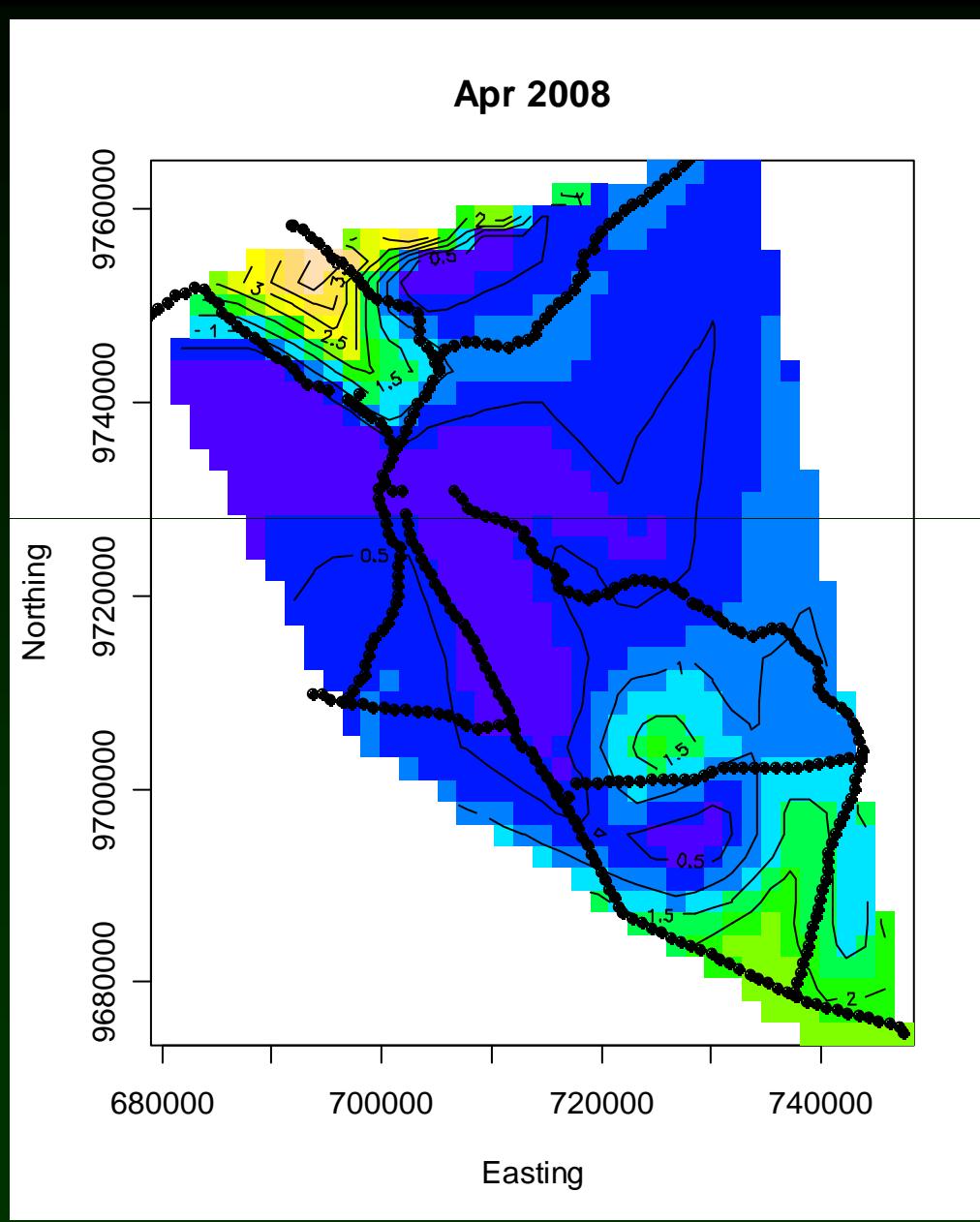
Topics

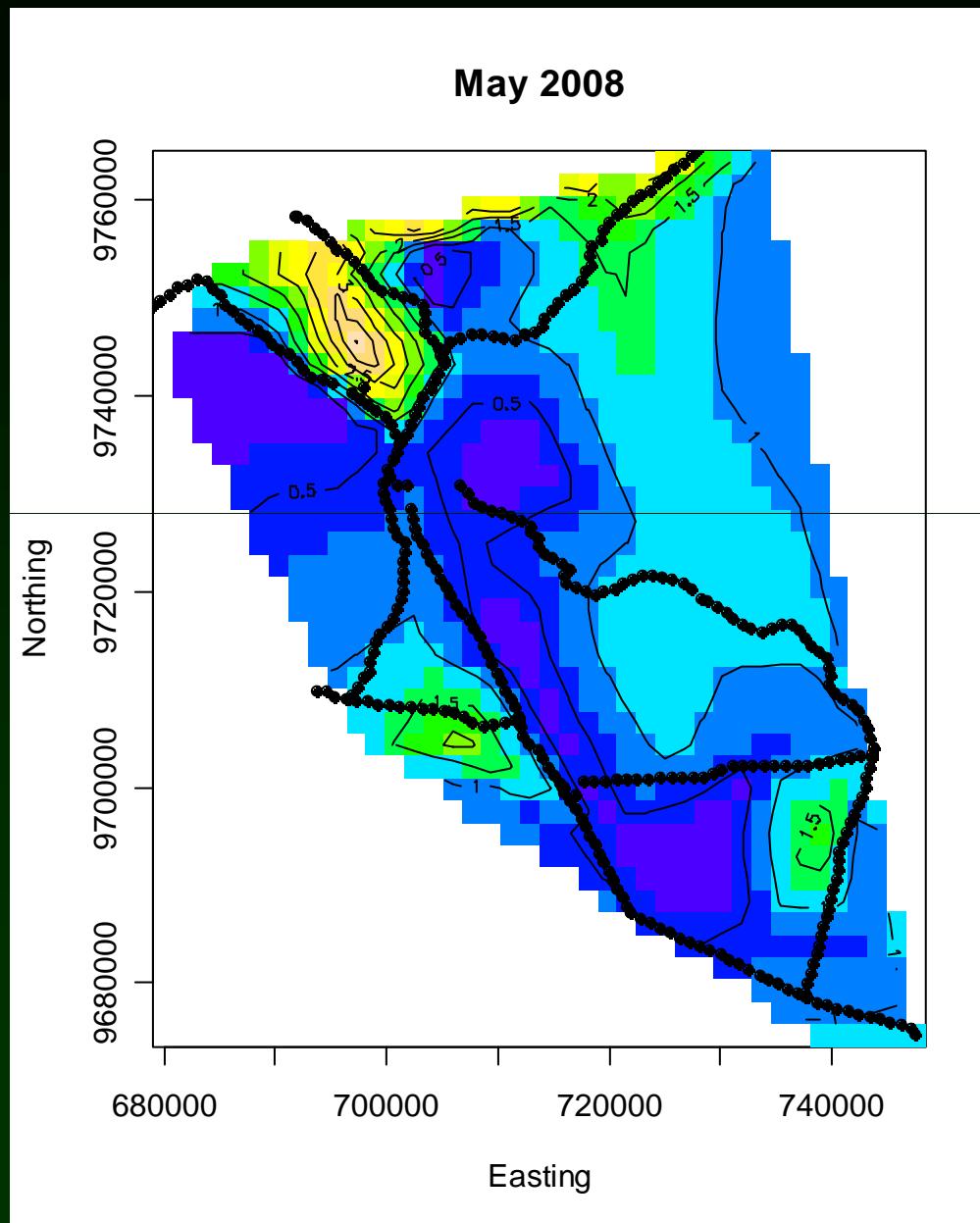
- Group formation and lion functional response
- Group formation and predator-prey dynamics
- Prey movement and lion-prey dynamics

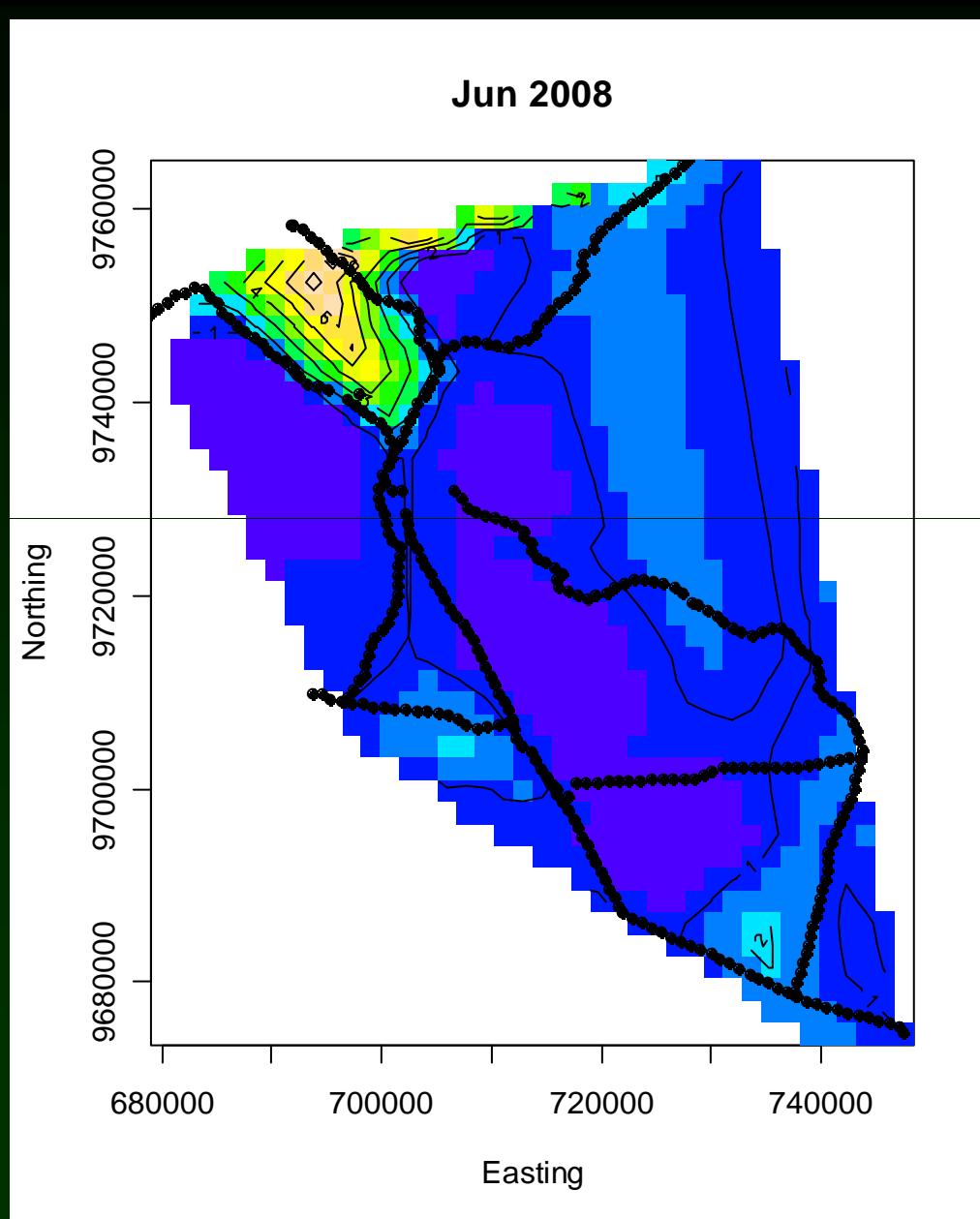


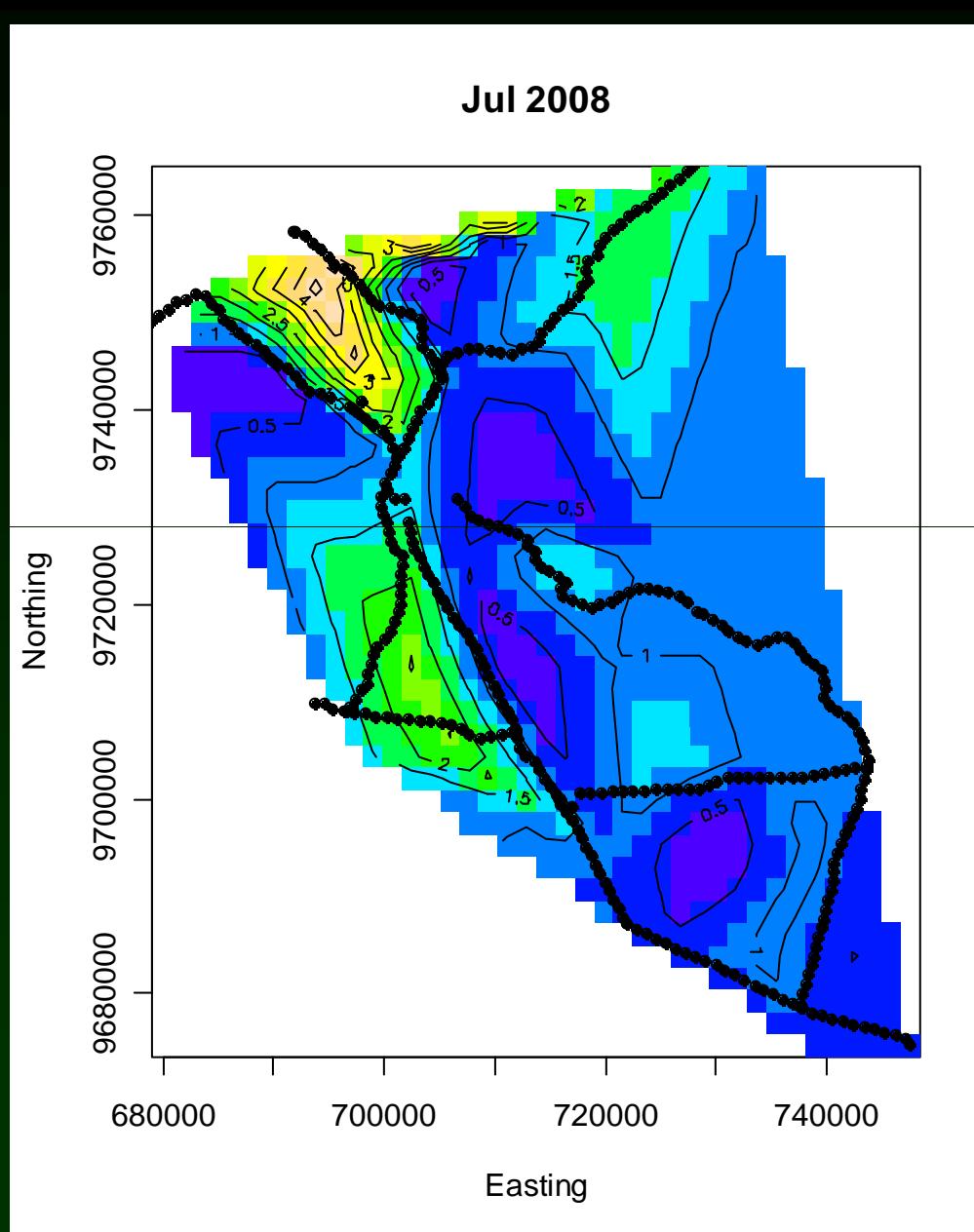


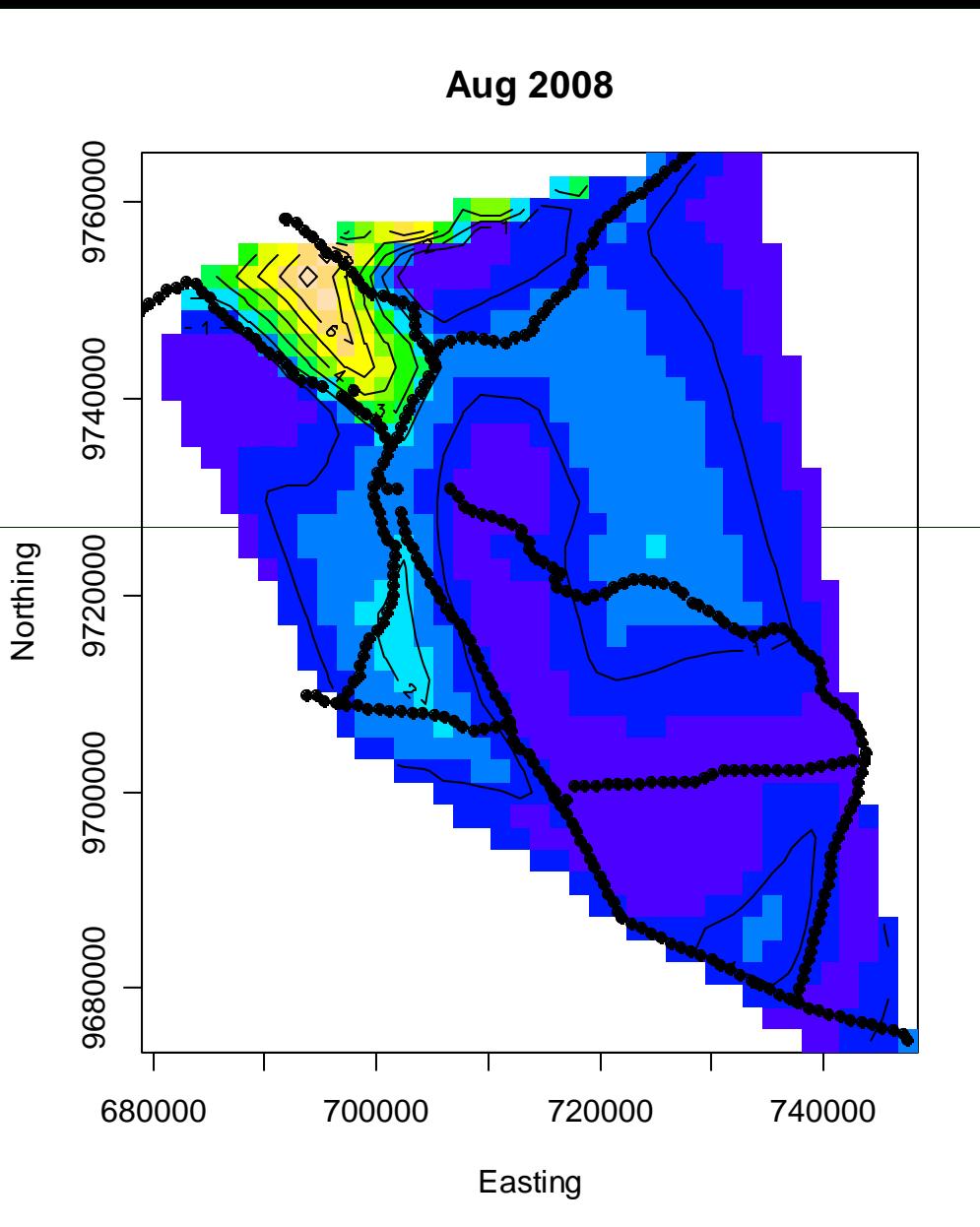


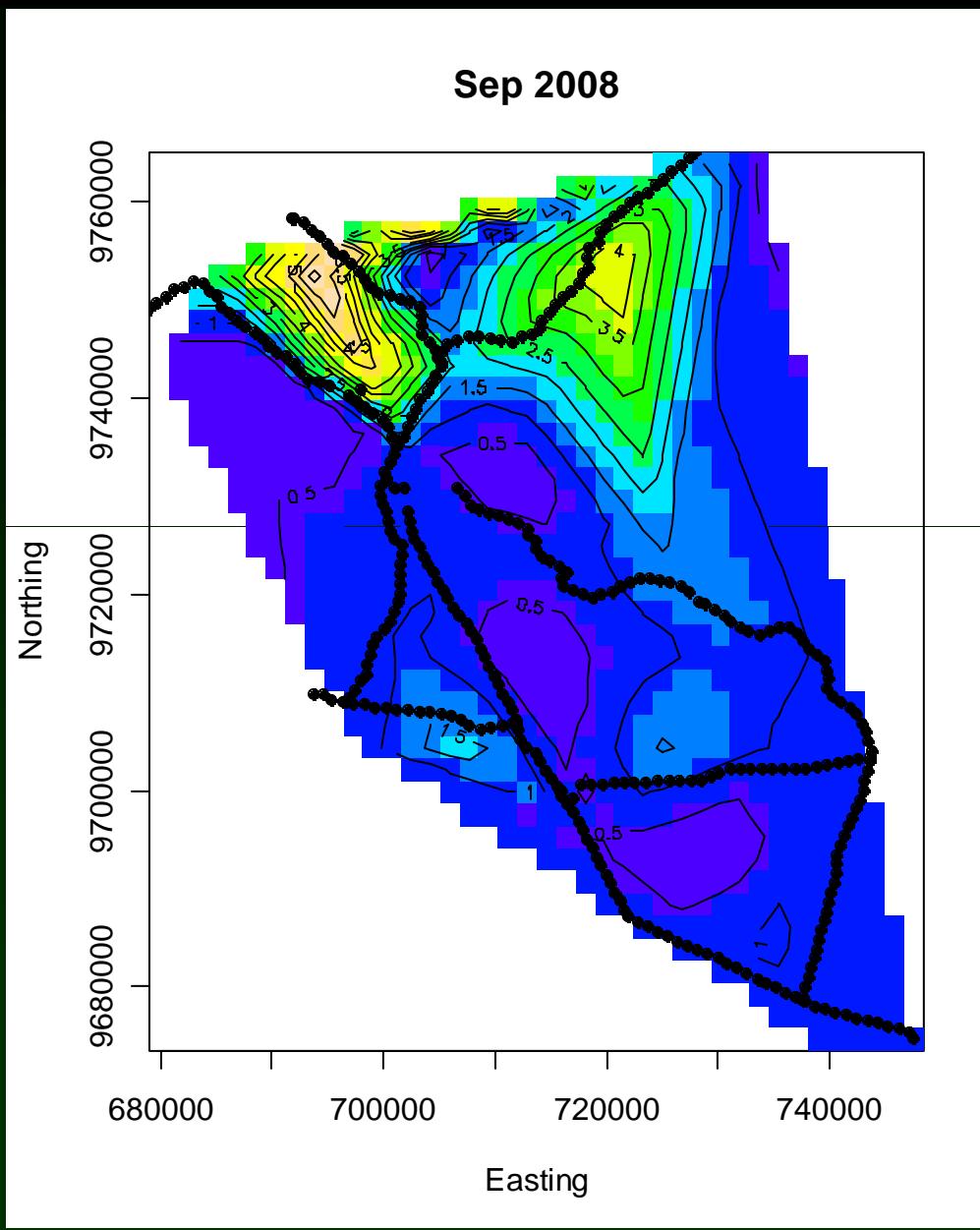


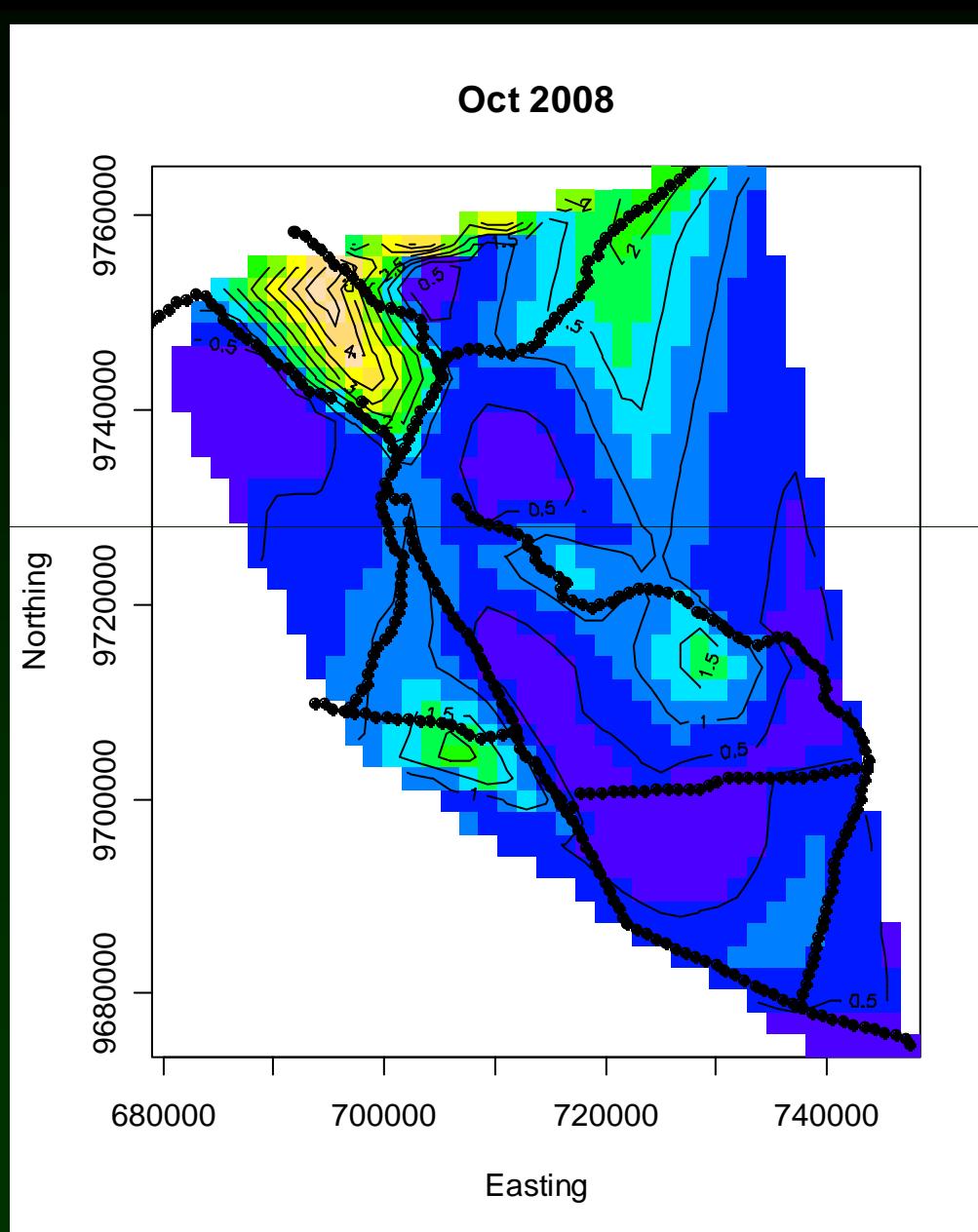


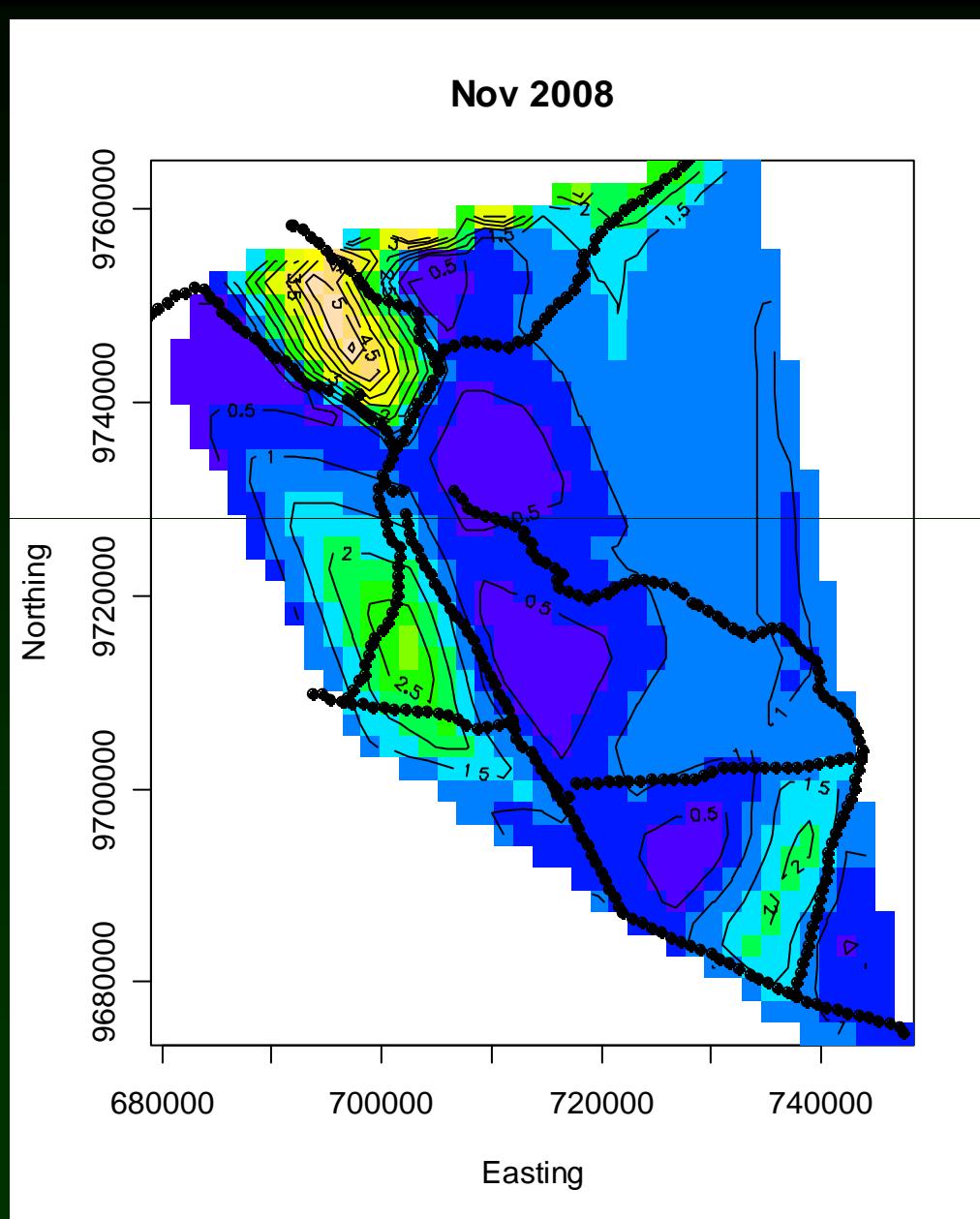


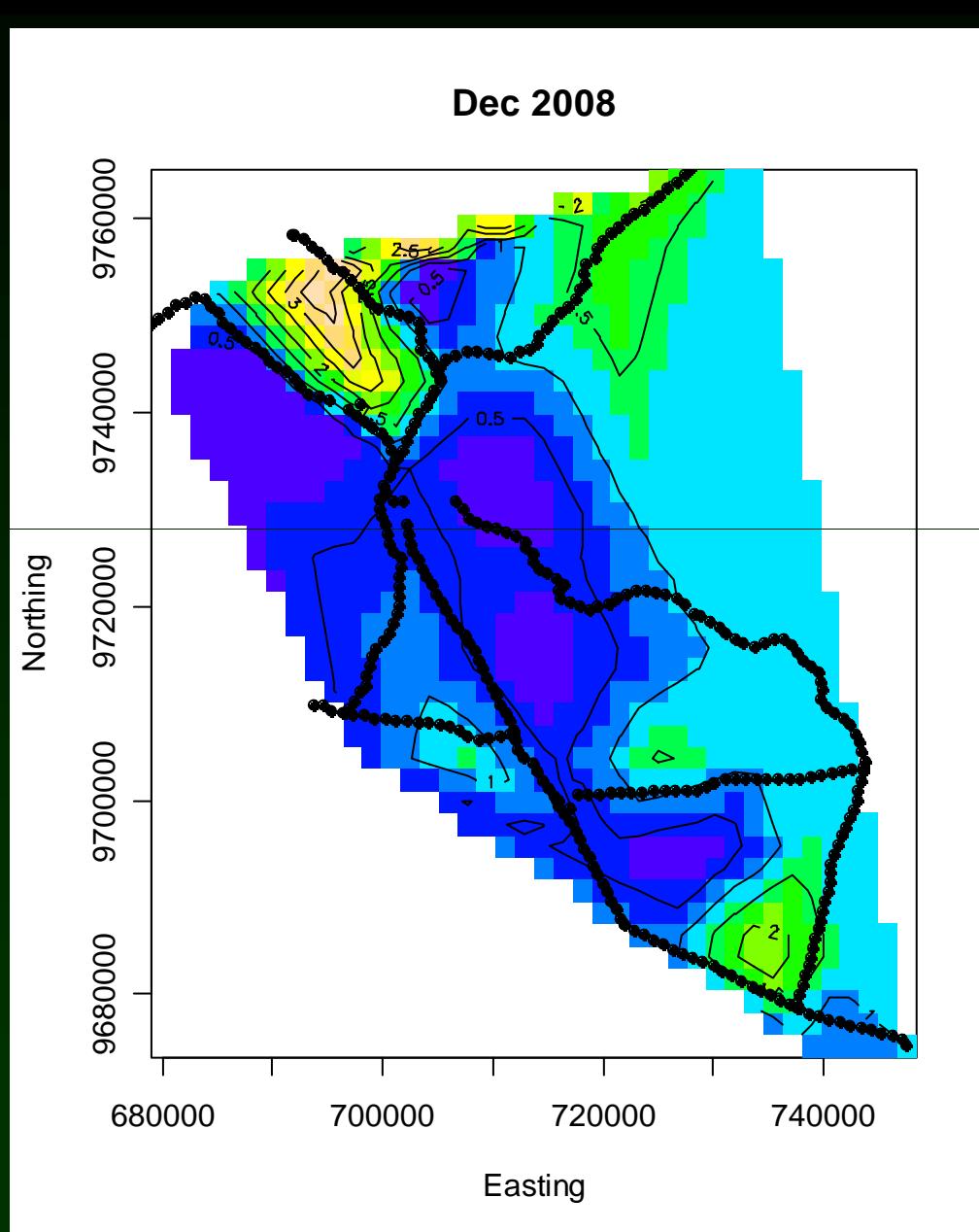


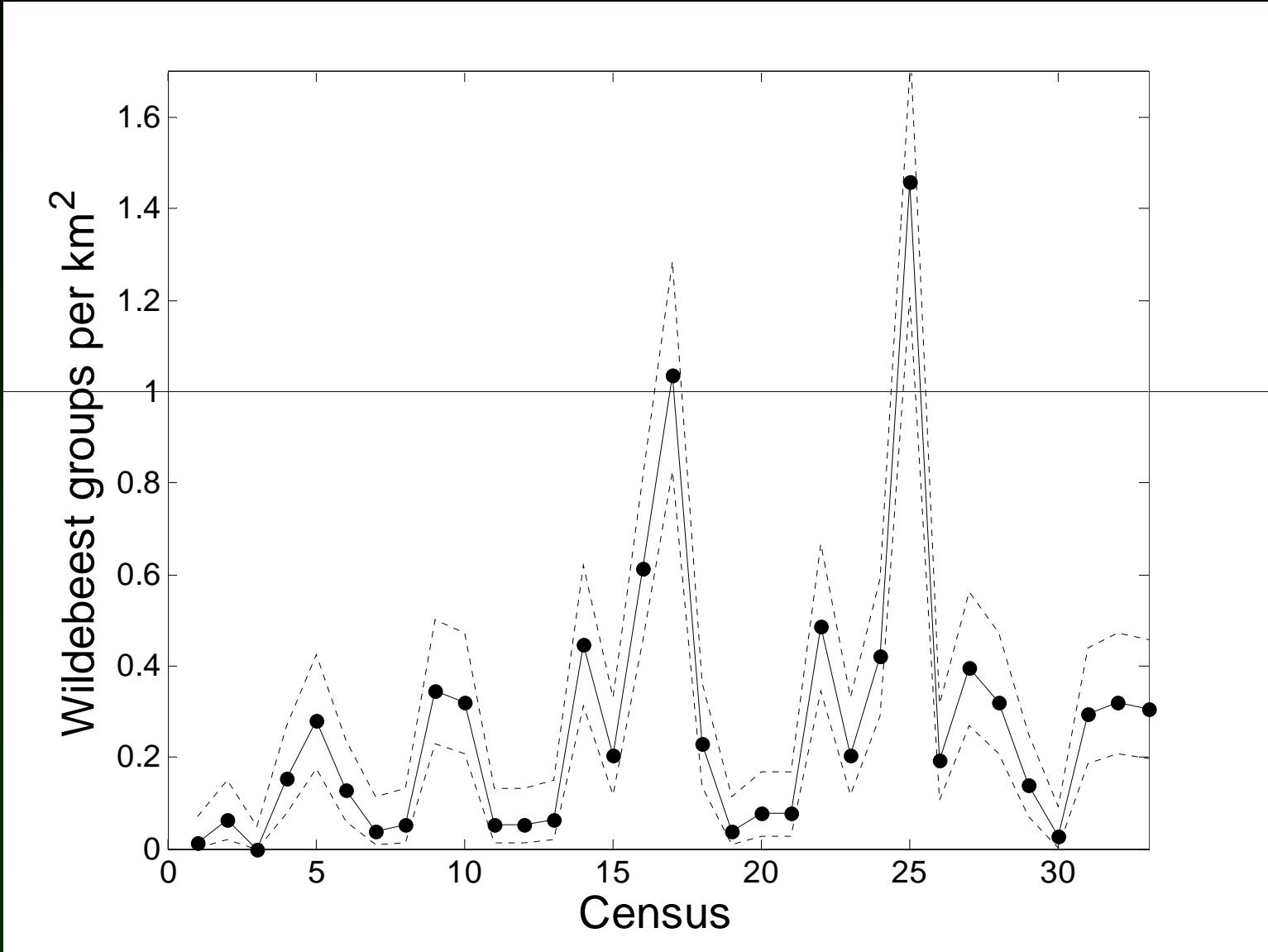


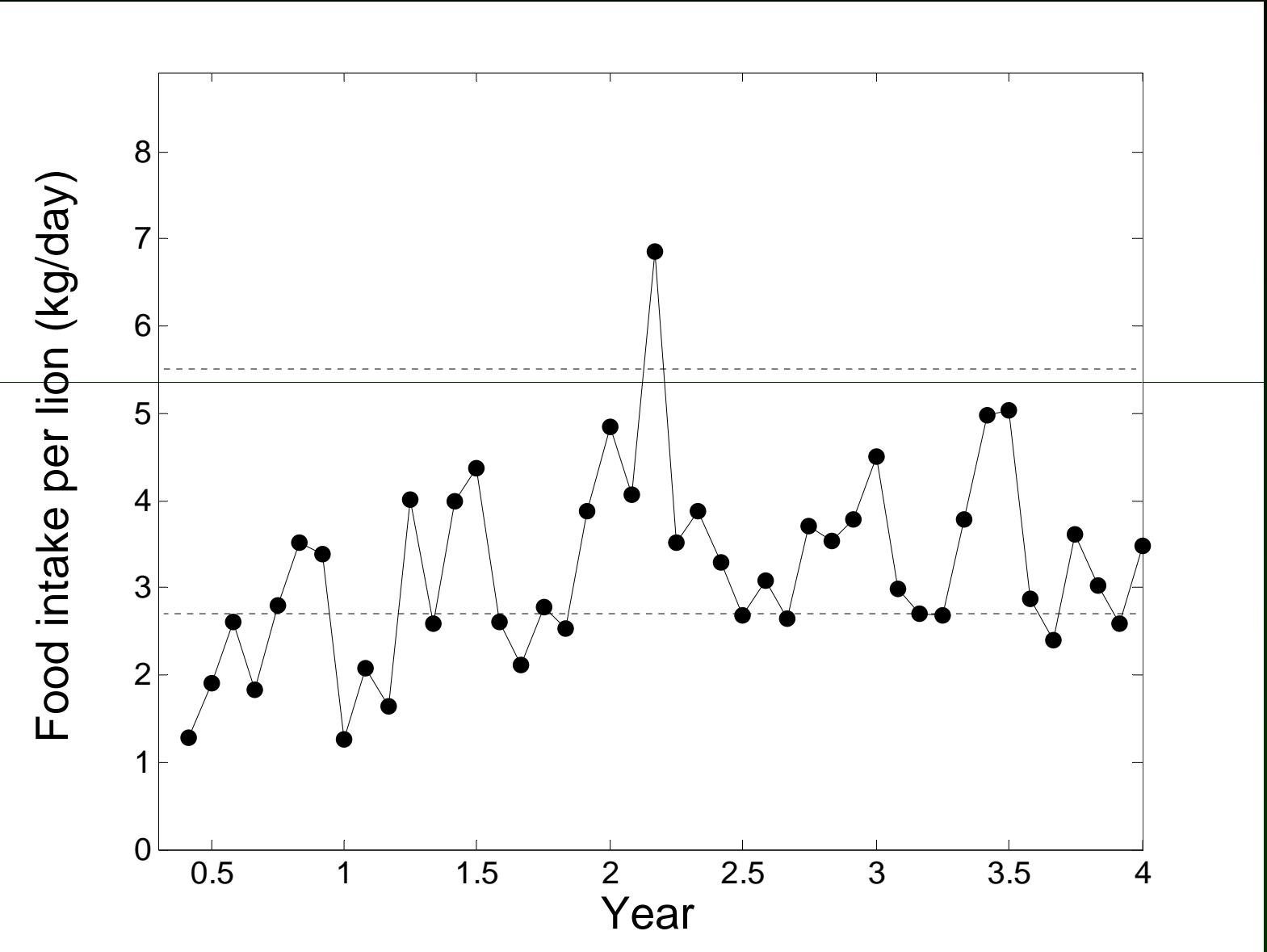








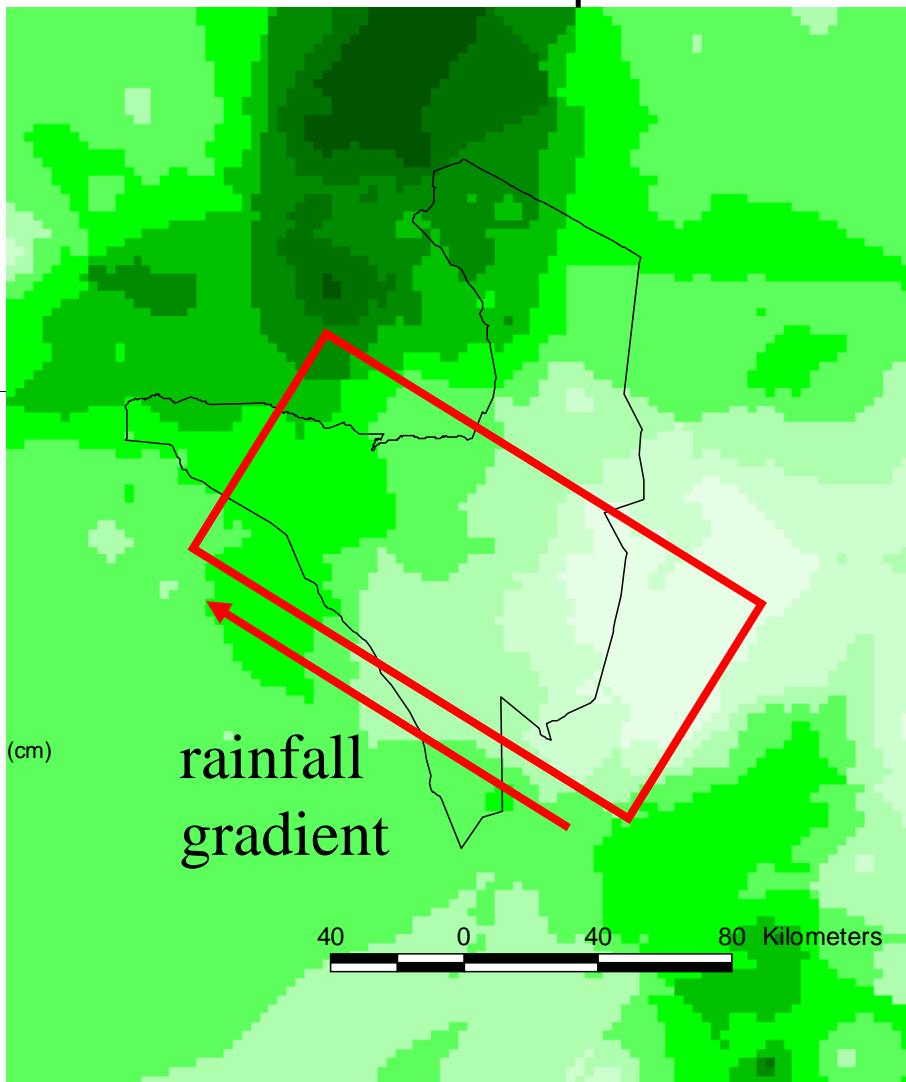
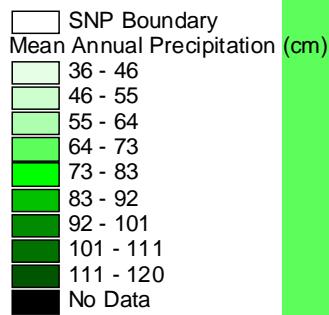




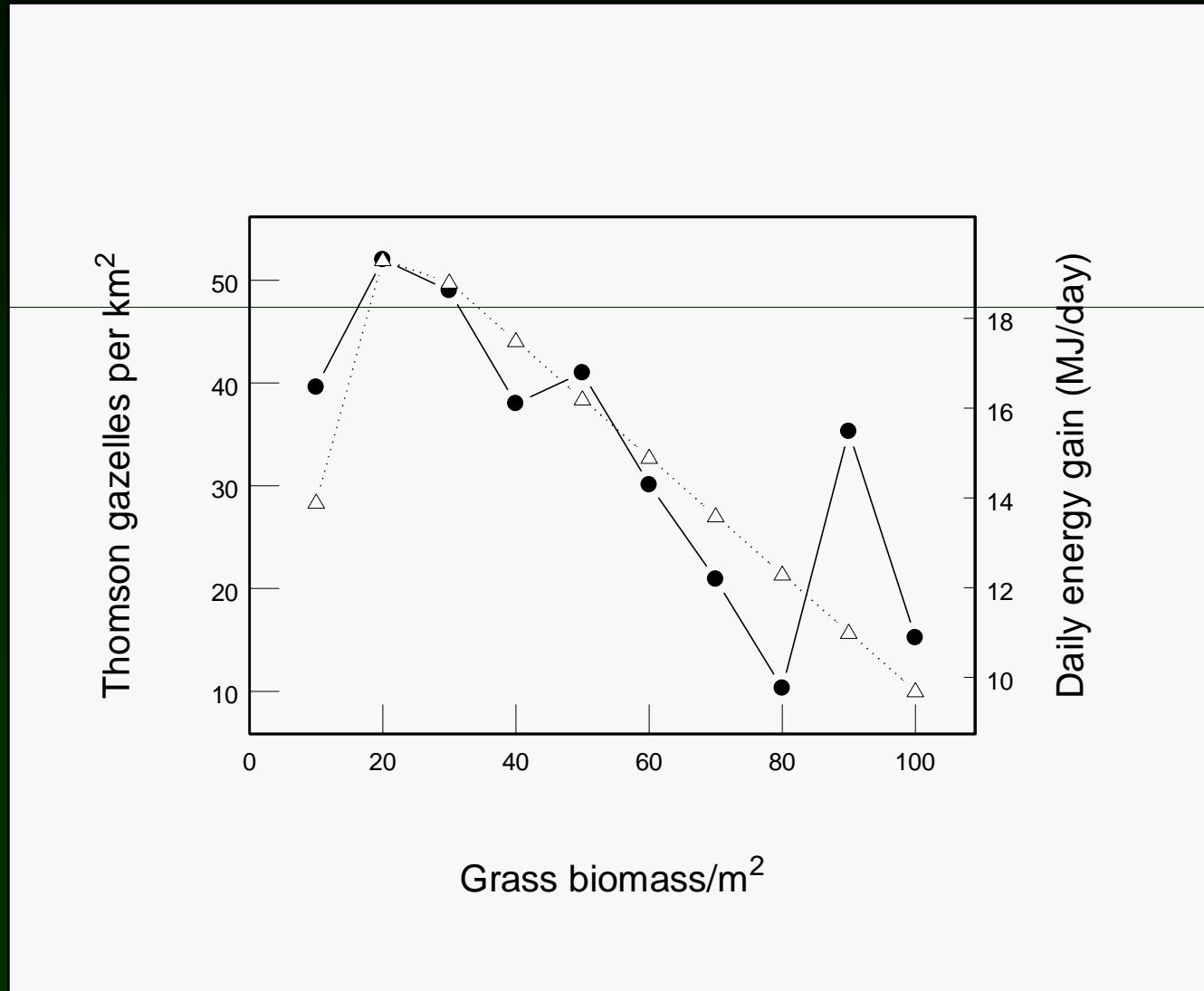
...as is the spatial location.



Mean Annual Precipitation

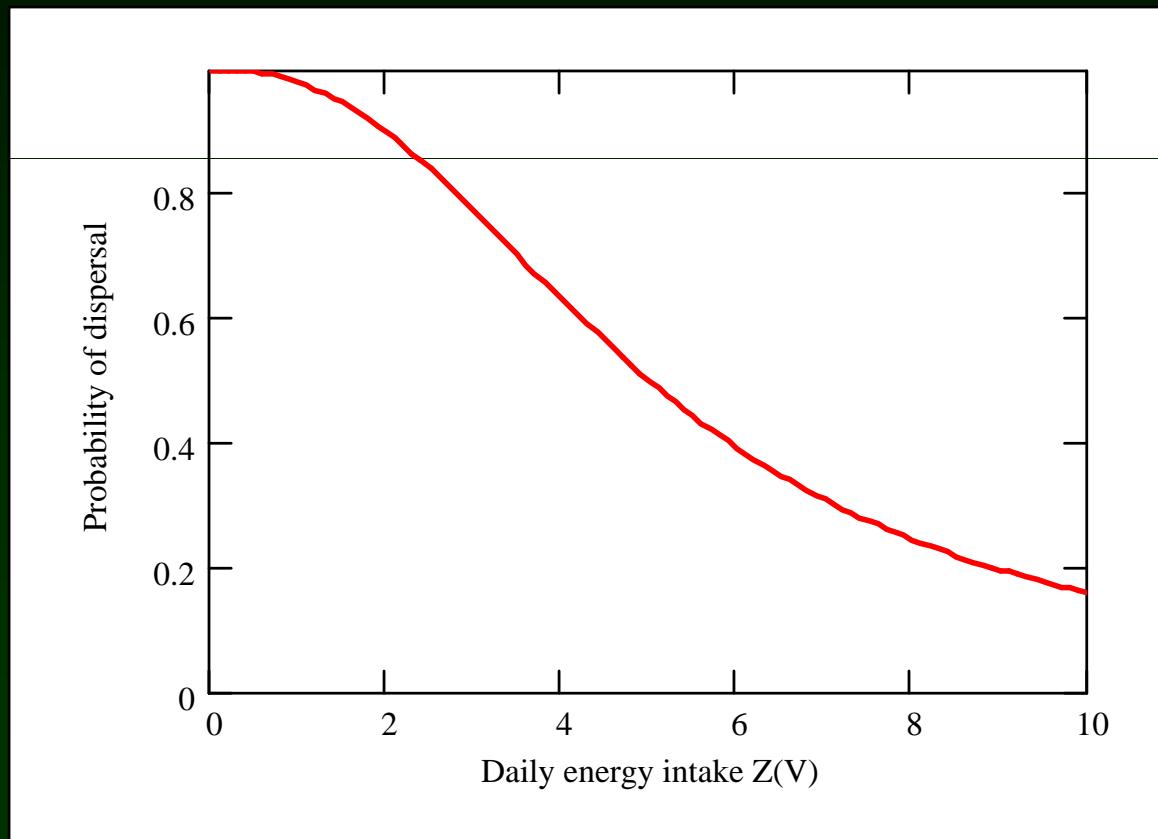


Movement by Thomson's gazelles tracks grass patches that optimize daily energy gain

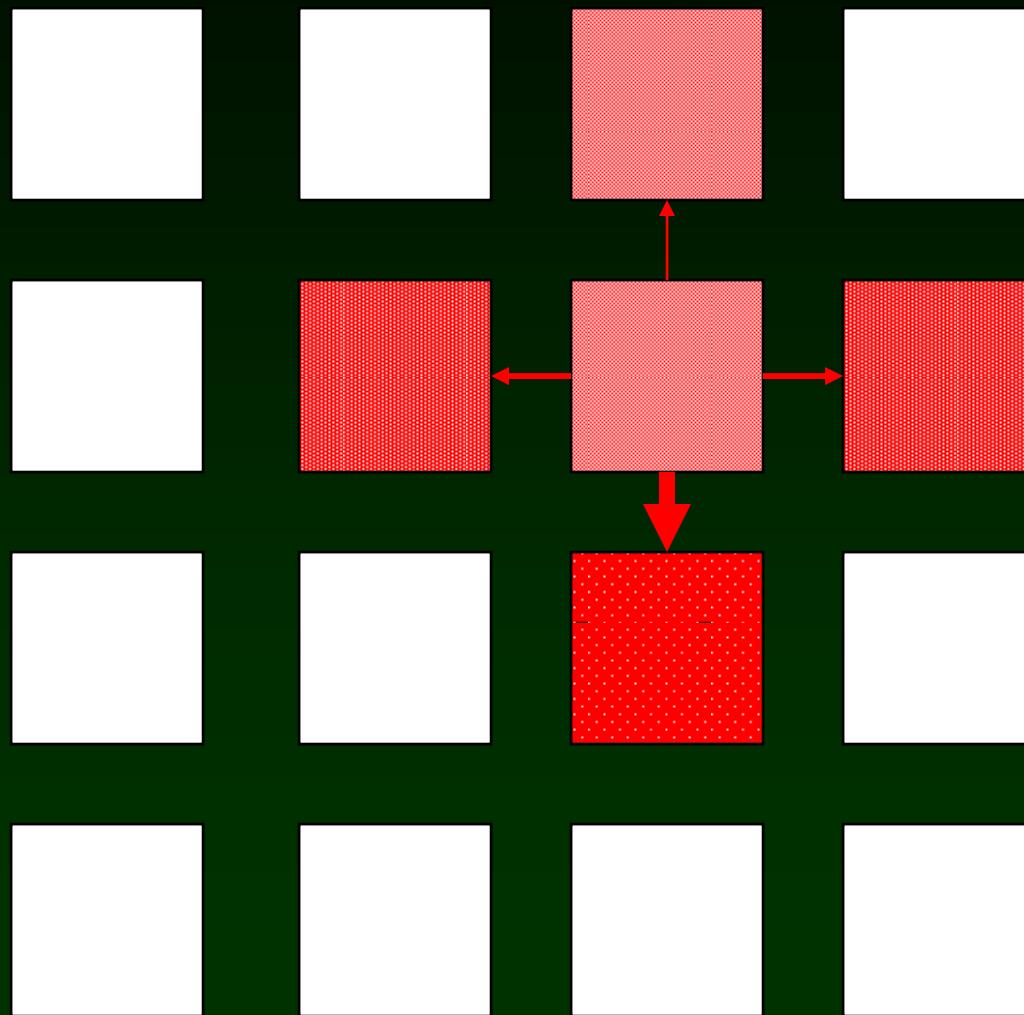


Adaptive patch departure model

Intake-dependent dispersal



Local energy-matching model



Coupled lattice map model:

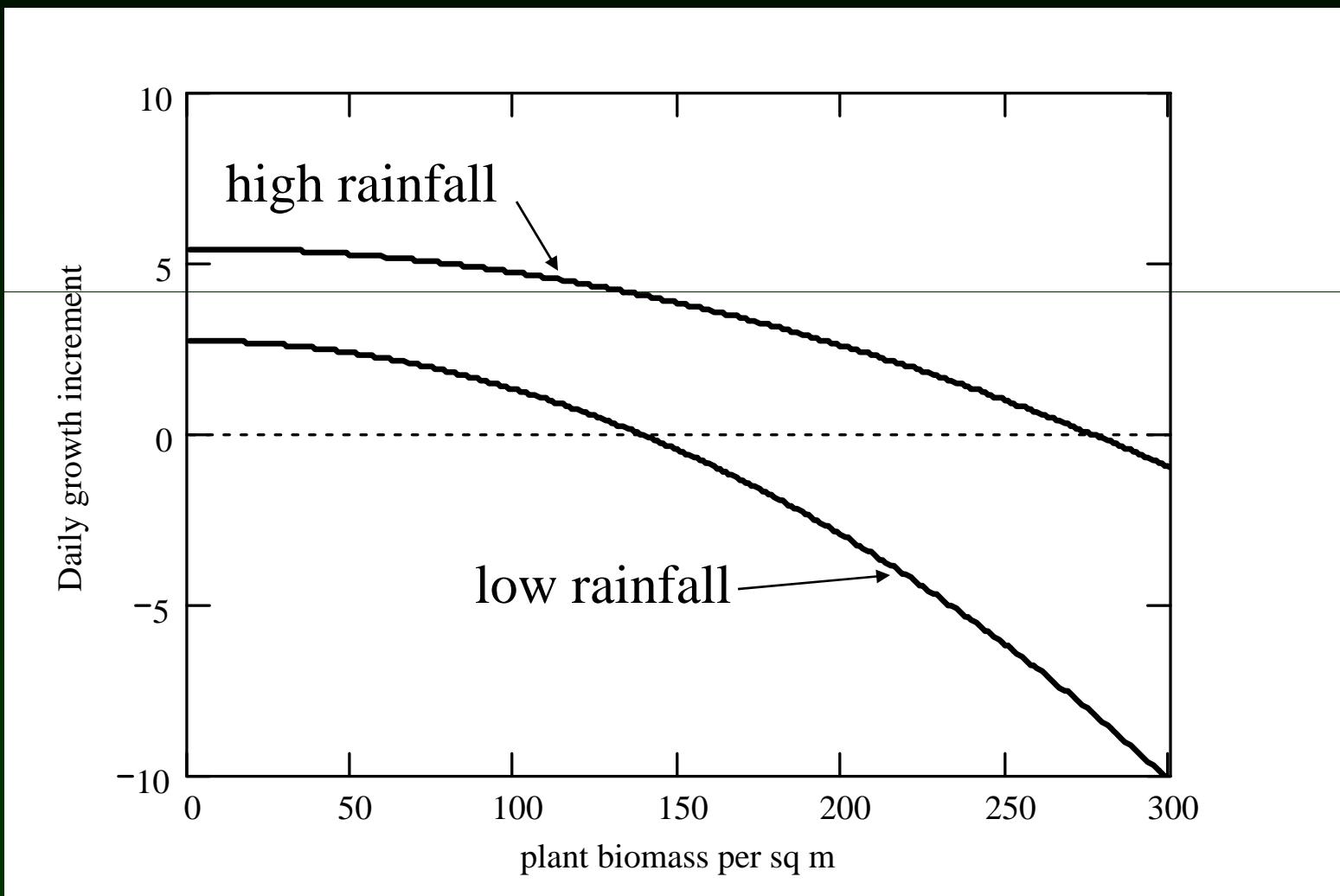
resource growth

$$\frac{dV_{ij}}{dt} = f(V_{ij}) - N_{ij}[\Omega(V_{ij}) - \theta(V_{ij})]W(V_{ij})$$

$$\frac{dN_{ij}}{dt} = N_{ij}[\Omega(V_{ij}) - \theta(V_{ij})][\Lambda(V_{ij})Z(V_{ij}) - \Gamma]$$

Grass growth in relation to

biomass and rainfall



Coupled lattice map model:

functional
response

$$\frac{dV_{ij}}{dt} = f(V_{ij}) - N_{ij} [\Omega(V_{ij}) - \theta(V_{ij})] W(V_{ij})$$

$$\frac{dN_{ij}}{dt} = N_{ij} [\Omega(V_{ij}) - \theta(V_{ij})] [\Lambda(V_{ij}) Z(V_{ij}) - \Gamma]$$

Coupled lattice map model:

$$\frac{dV_{ij}}{dt} = f(V_{ij}) - N_{ij} [\Omega(V_{ij}) - \theta(V_{ij})] W(V_{ij})$$

$$\frac{dN_{ij}}{dt} = N_{ij} [\Omega(V_{ij}) - \theta(V_{ij})] [\Lambda(V_{ij}) Z(V_{ij}) - \Gamma]$$

spatial
response

Coupled lattice map model:

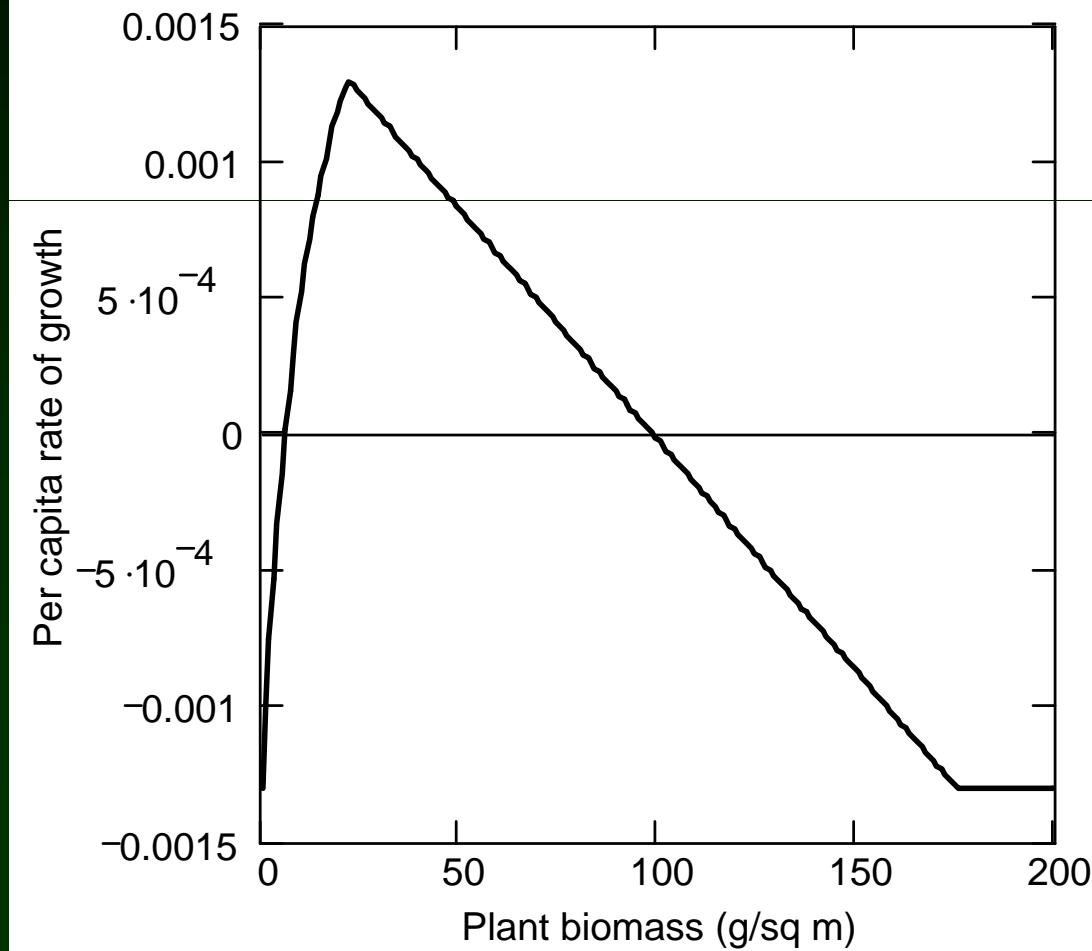
$$\frac{dV_{ij}}{dt} = f(V_{ij}) - N_{ij}[\Omega(V_{ij}) - \theta(V_{ij})]W(V_{ij})$$

$$\frac{dN_{ij}}{dt} = N_{ij}[\Omega(V_{ij}) - \theta(V_{ij})][\Lambda(V_{ij})Z(V_{ij}) - \Gamma]$$

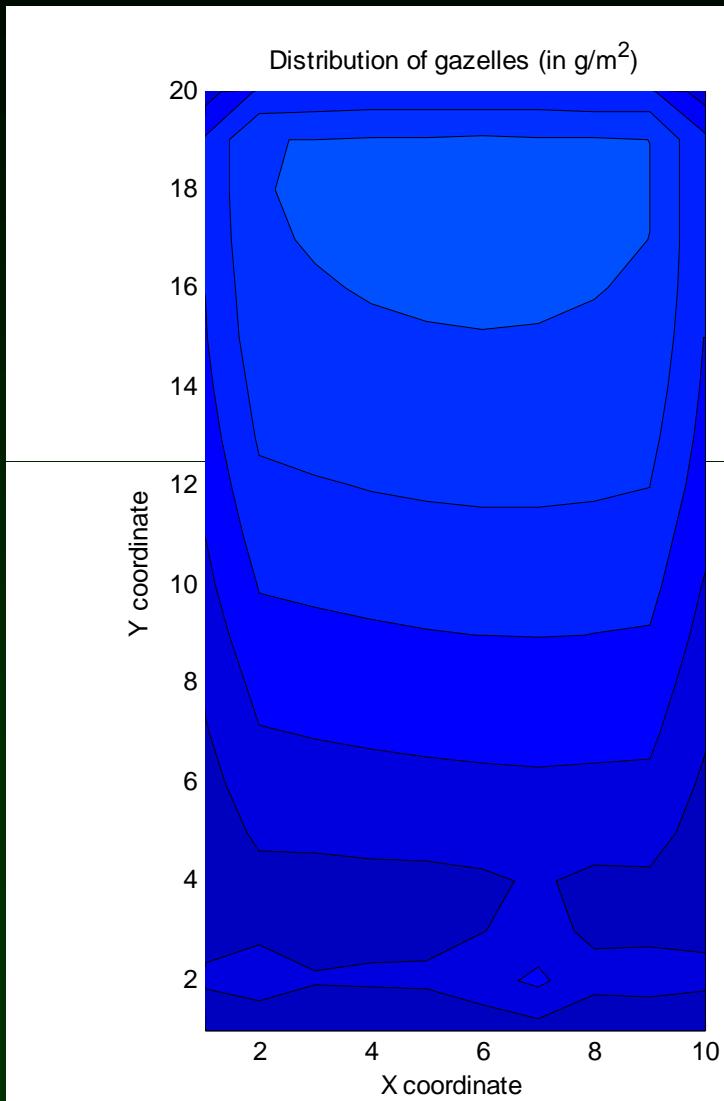
numerical
response

Per capita rate of herbivore increase relative to plant biomass

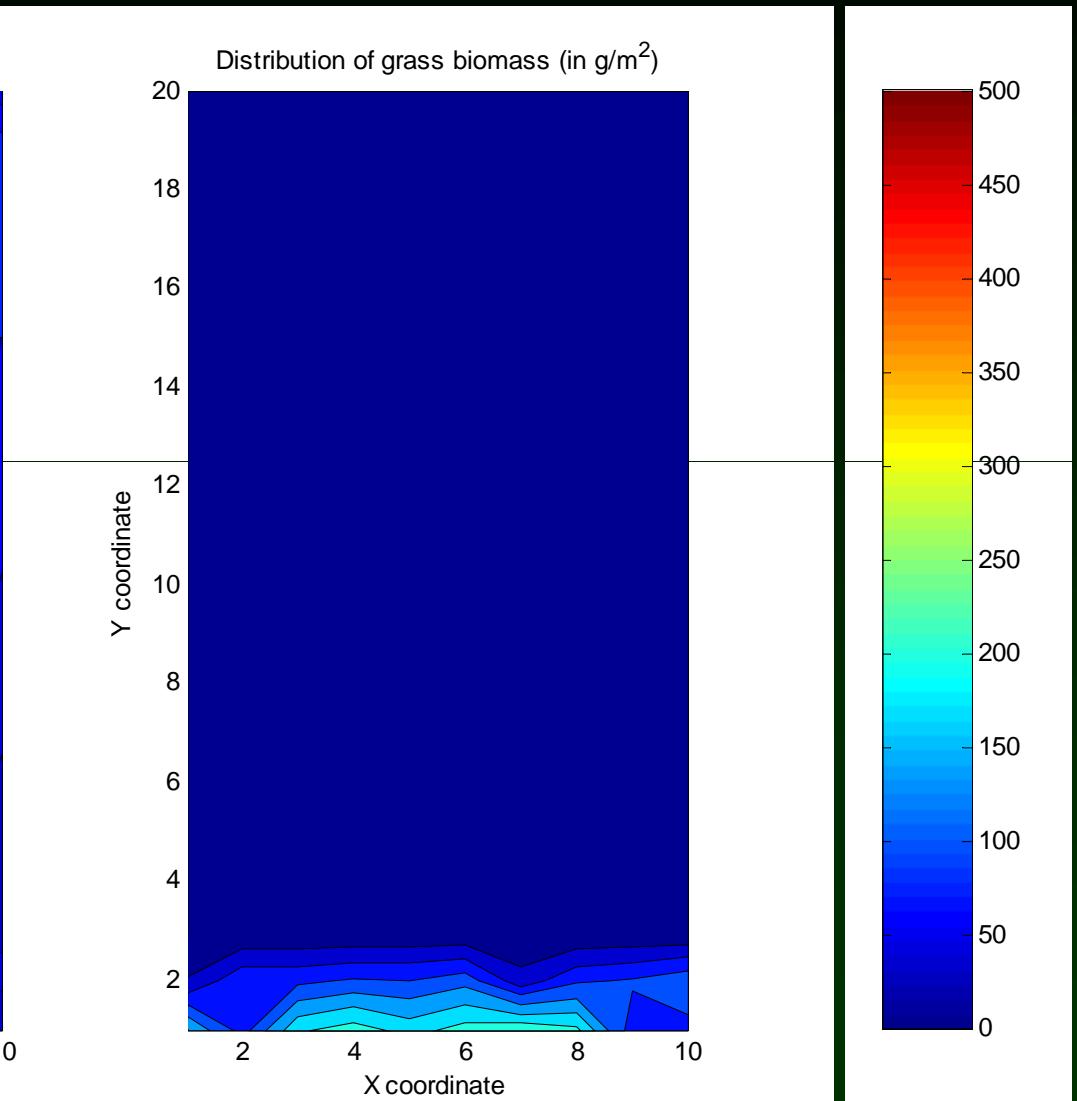
$$\text{percapgrowth}(V) = (Z(V) \cdot \Lambda - \Gamma)$$



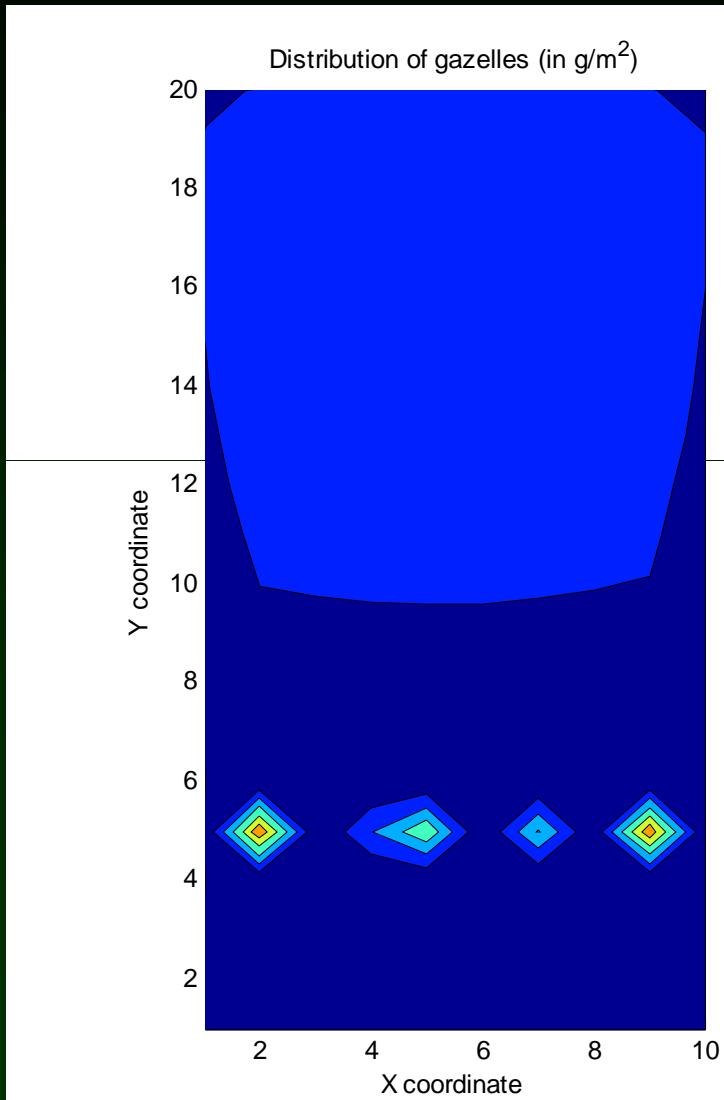
Thomson's gazelles



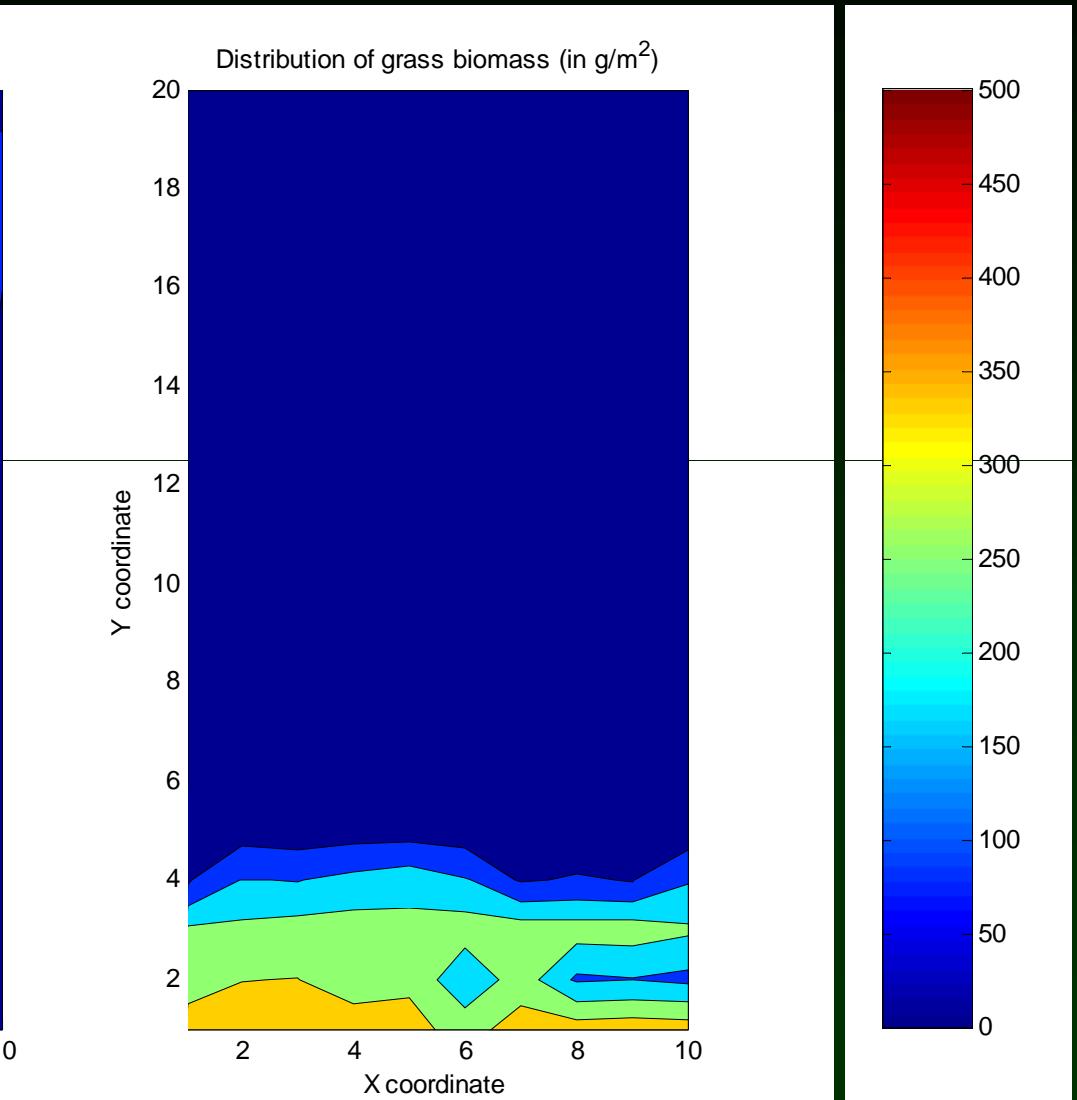
Grass biomass



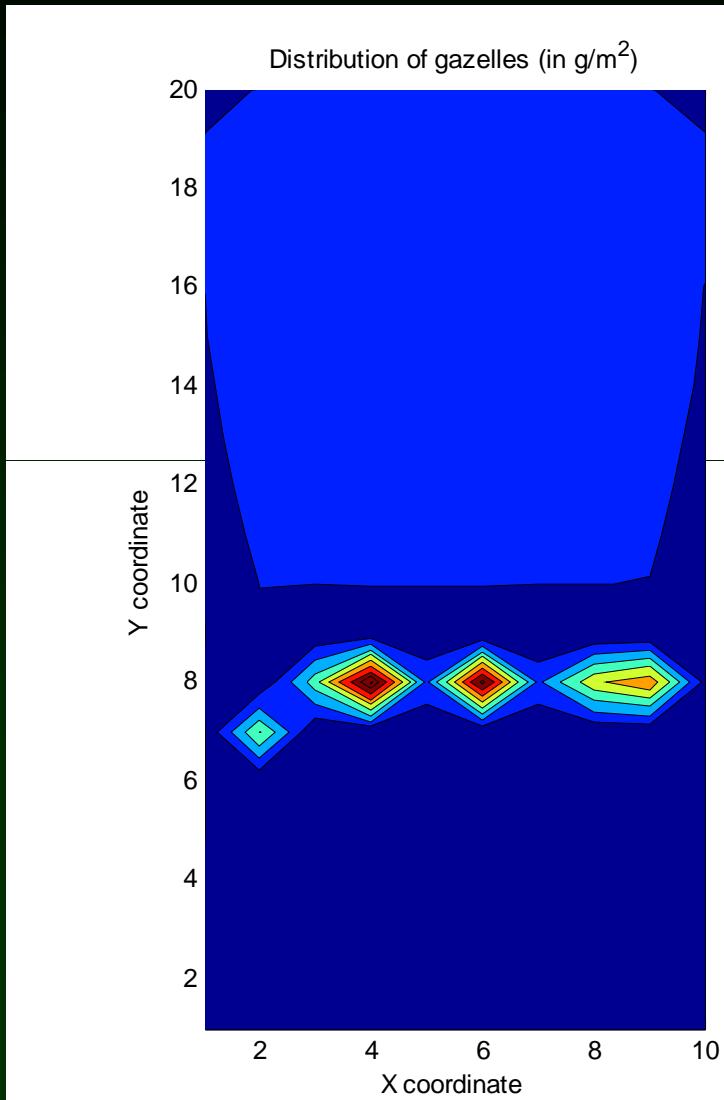
Thomson's gazelles



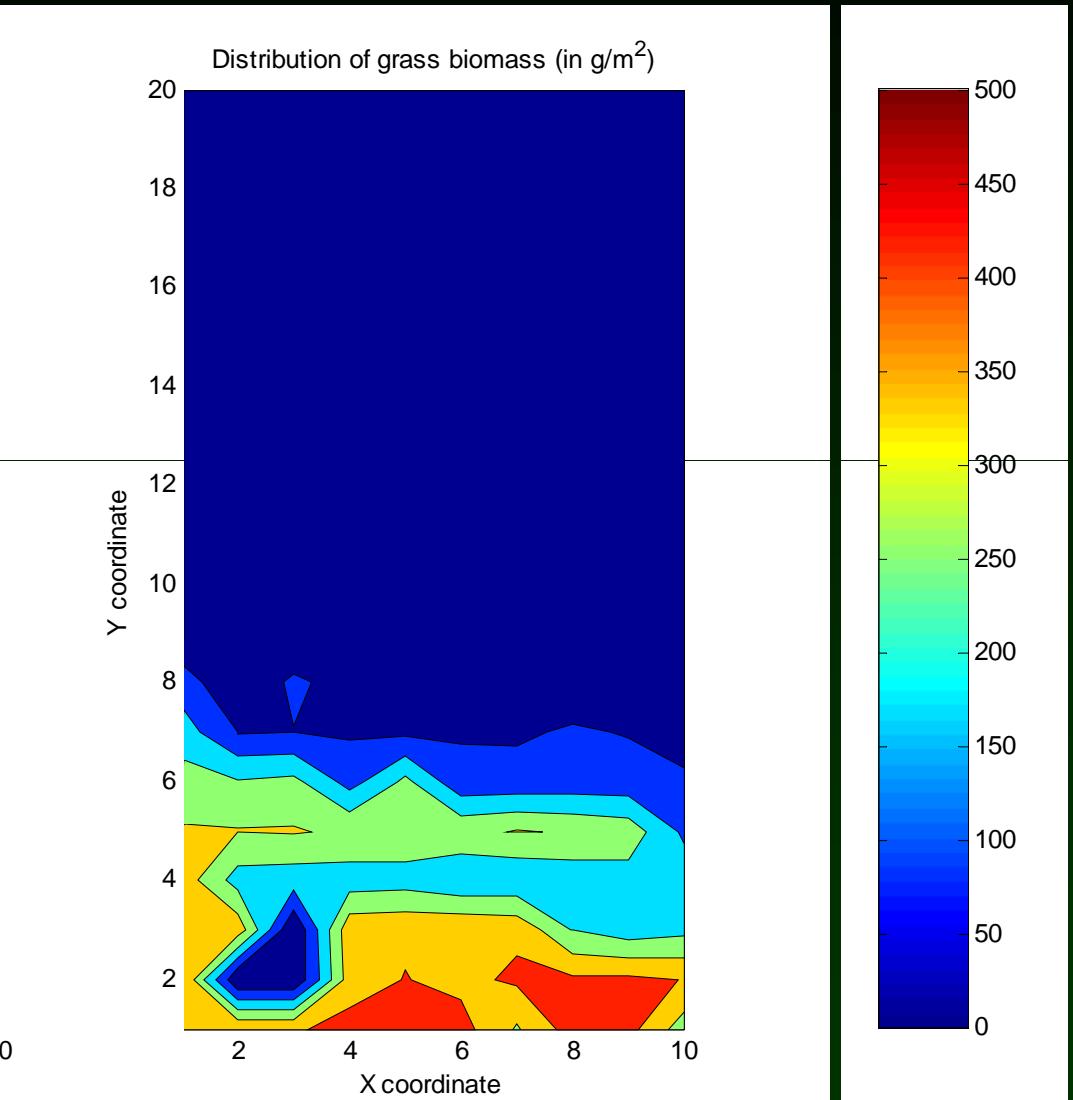
Grass biomass



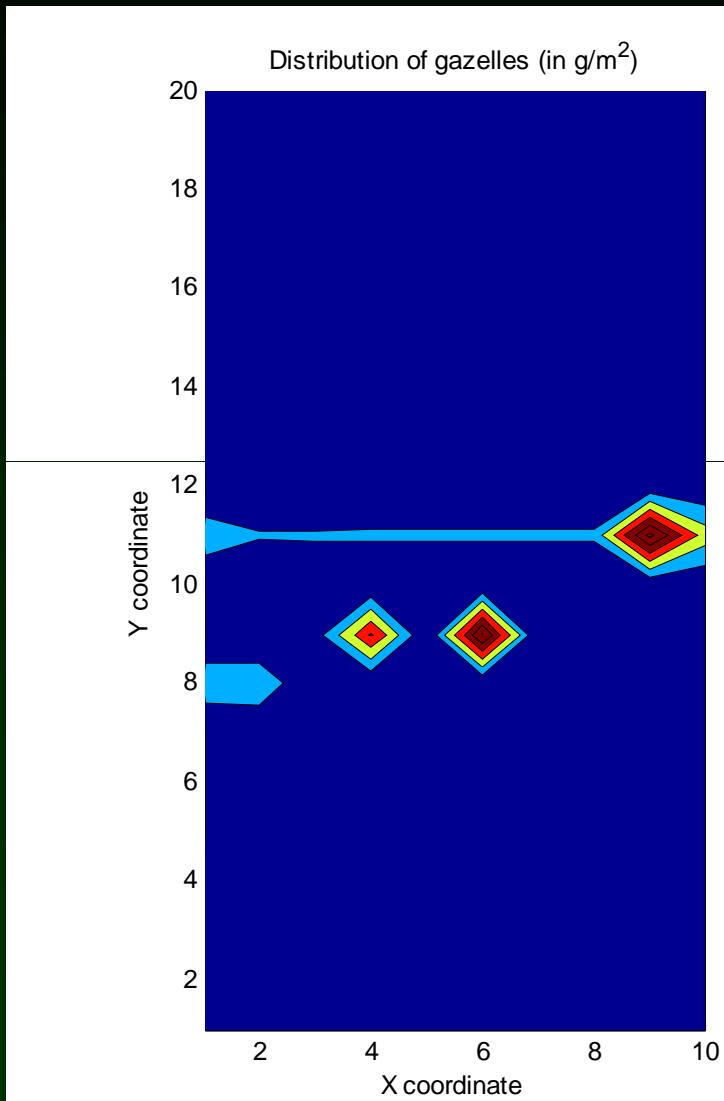
Thomson's gazelles



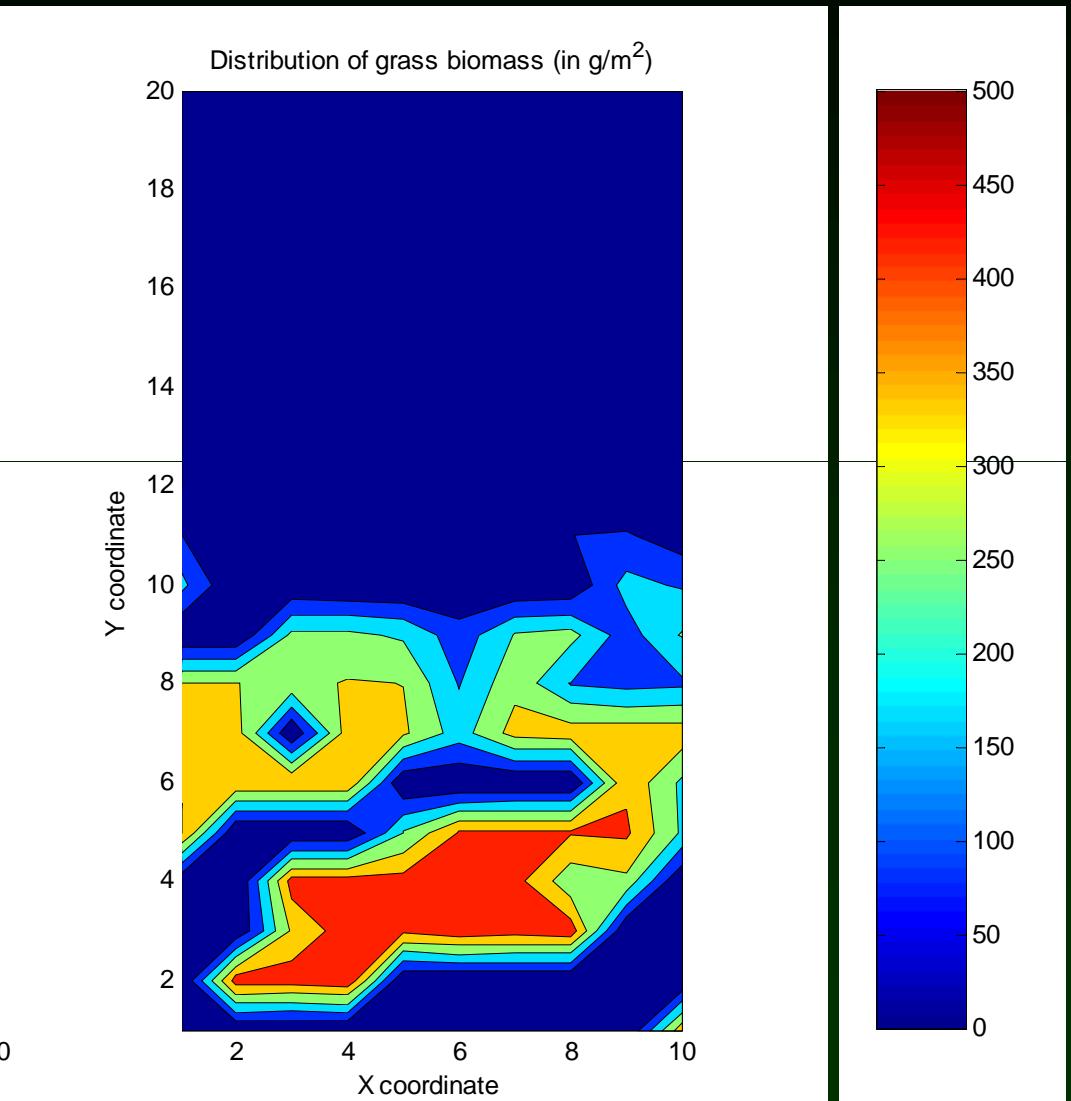
Grass biomass



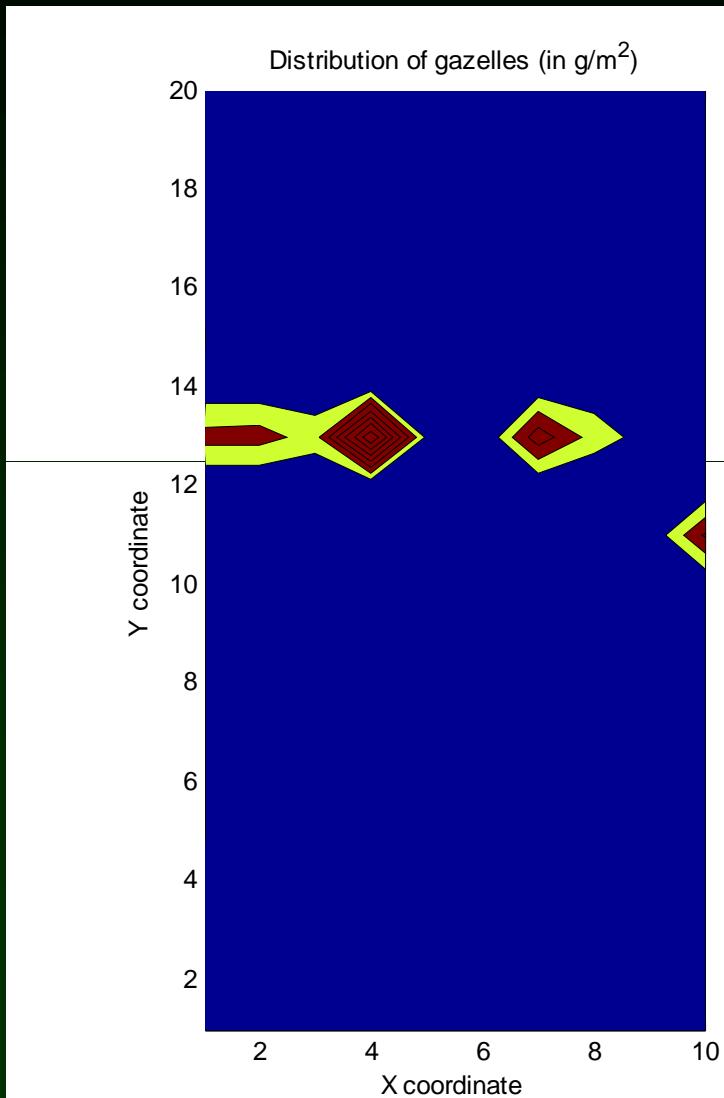
Thomson's gazelles



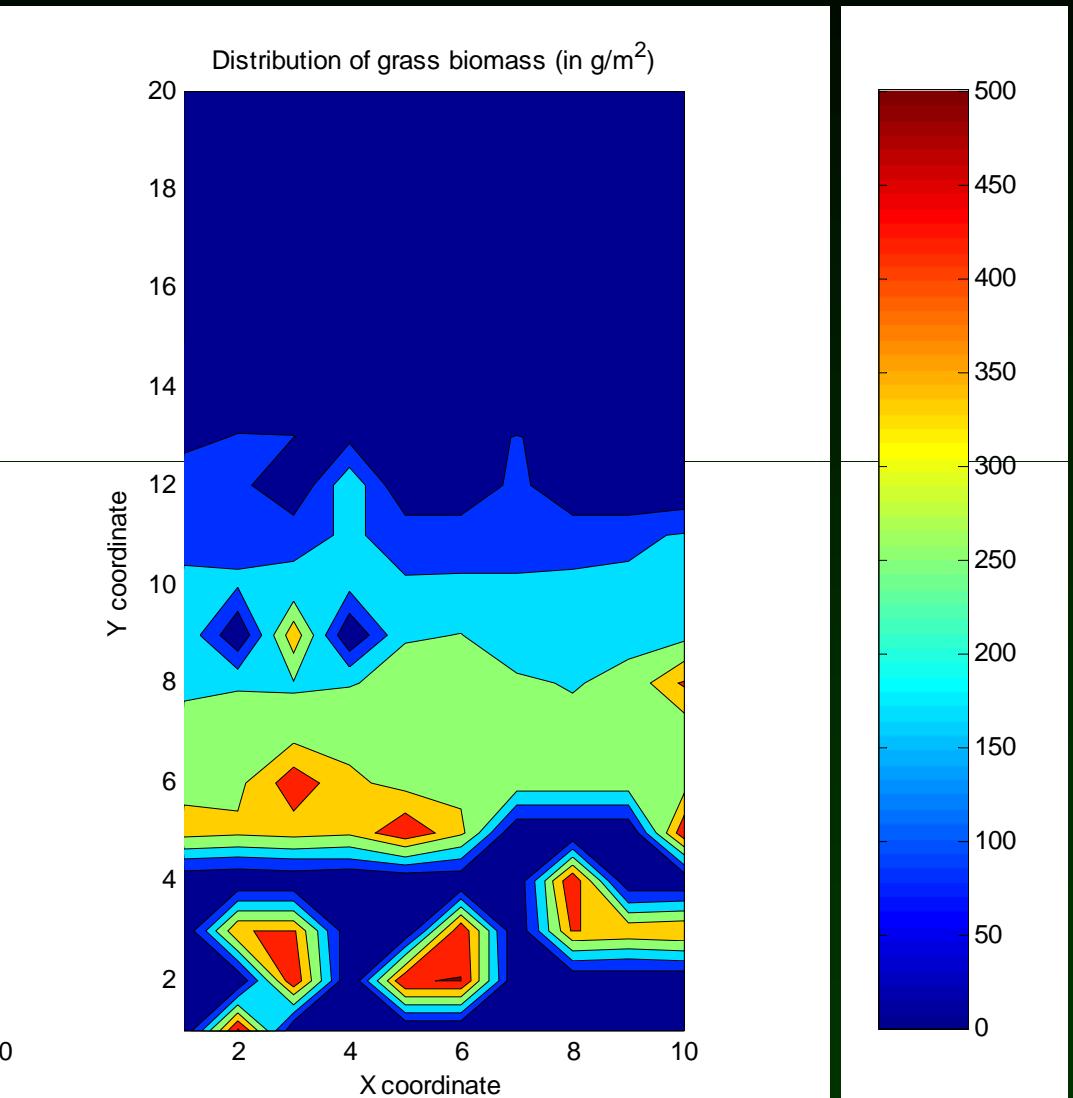
Grass biomass



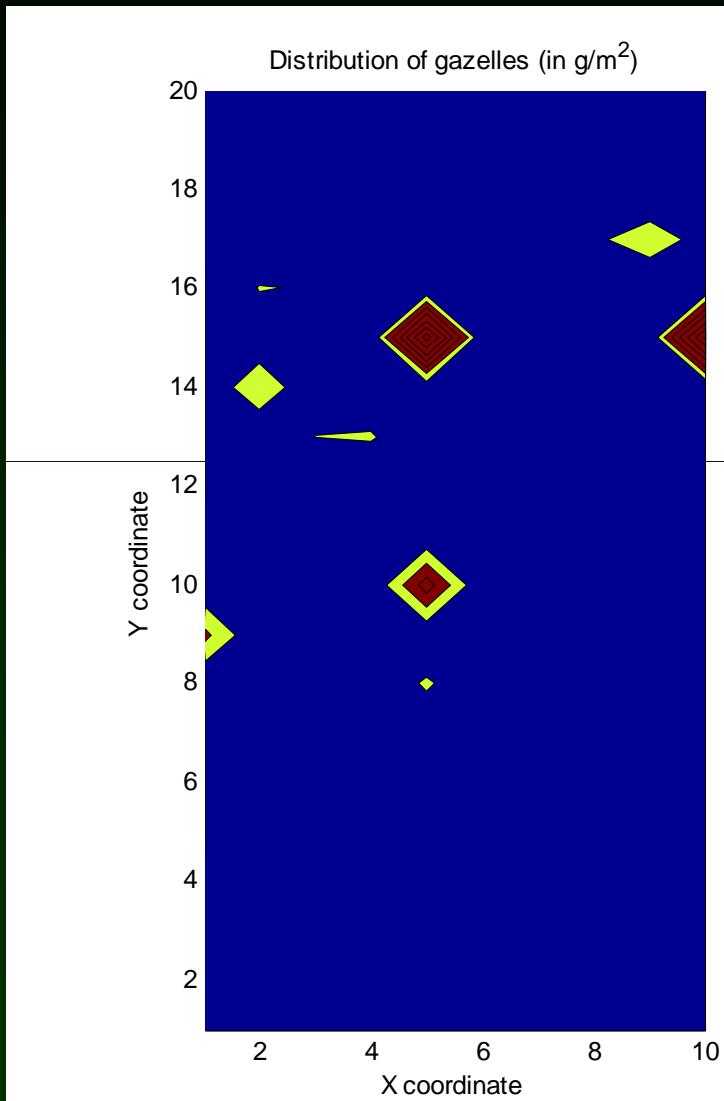
Thomson's gazelles



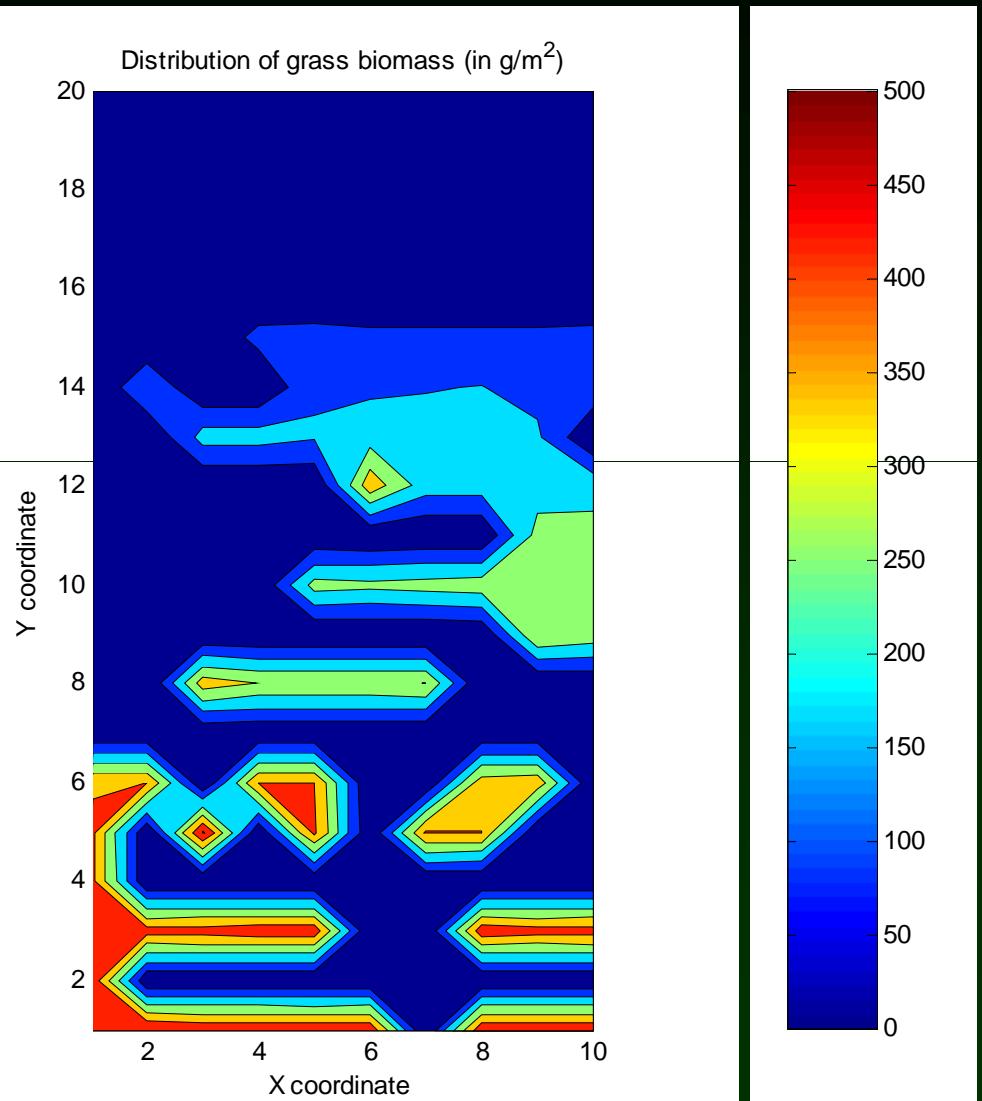
Grass biomass



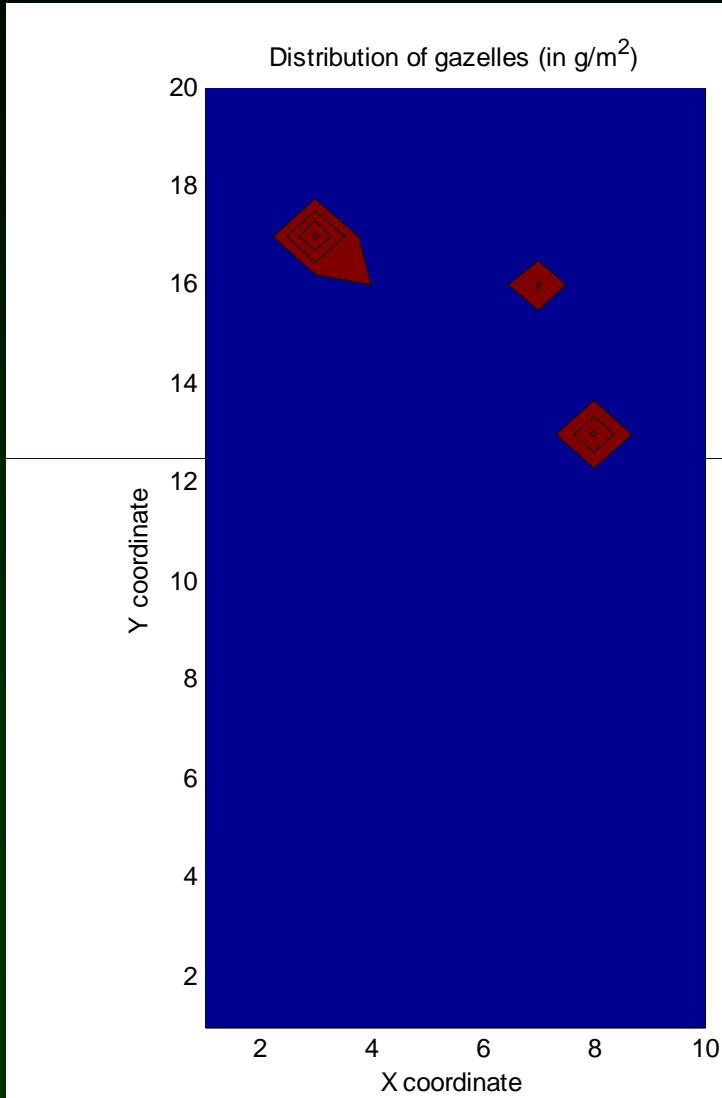
Thomson's gazelles



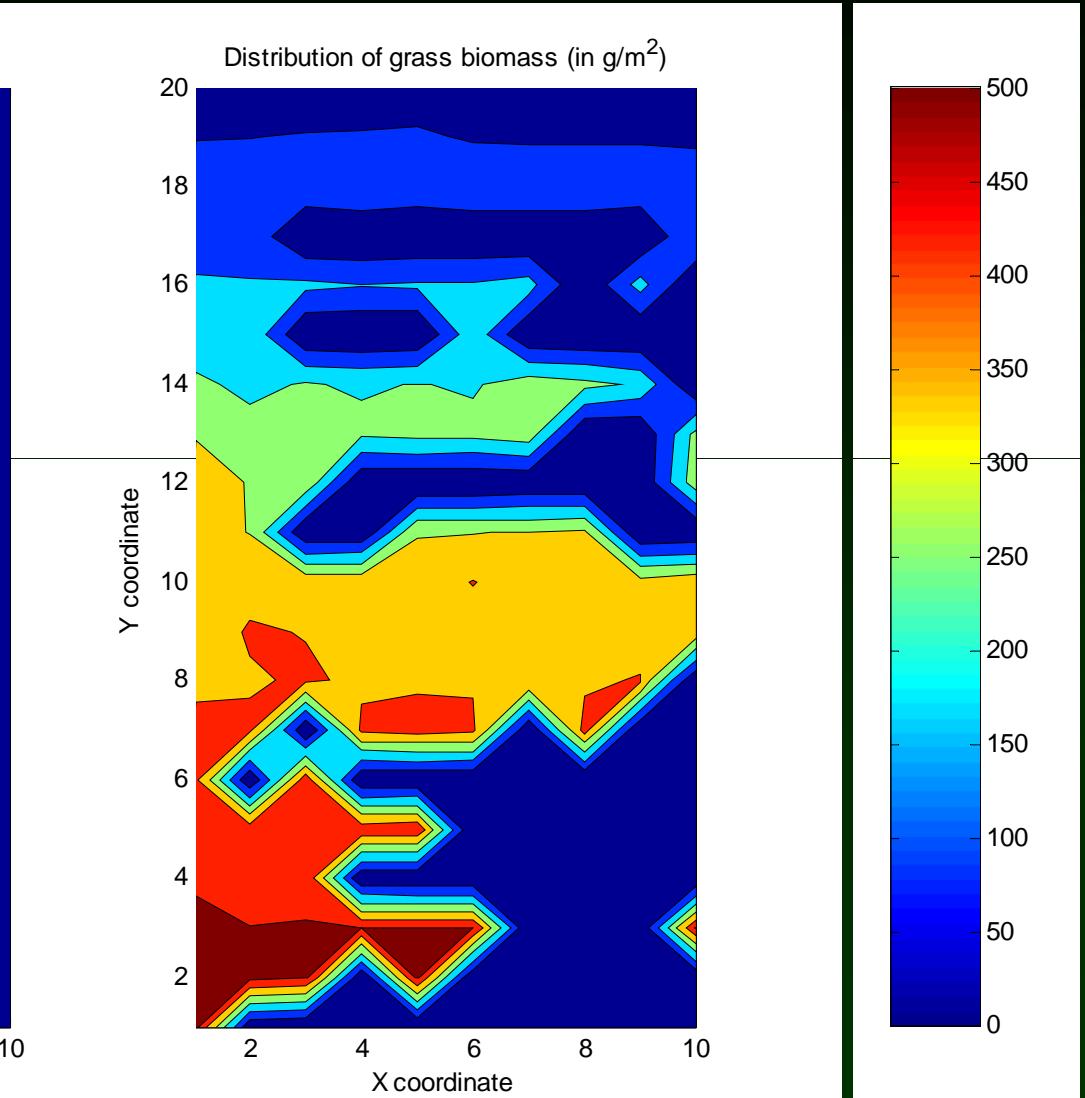
Grass biomass



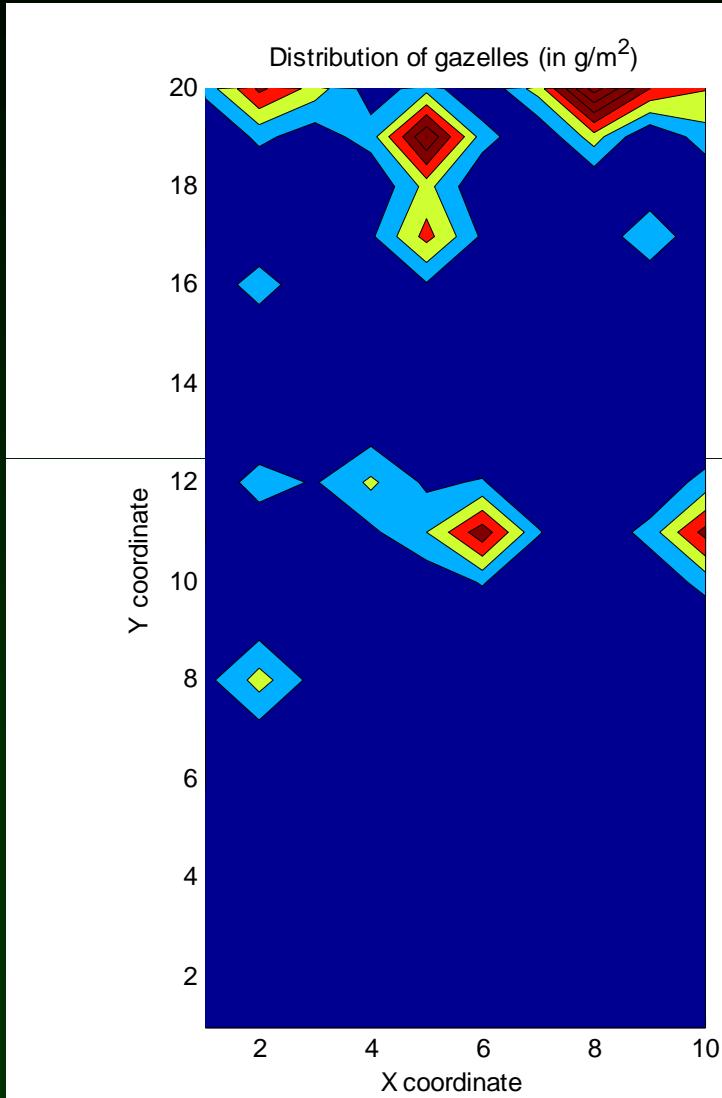
Thomson's gazelles



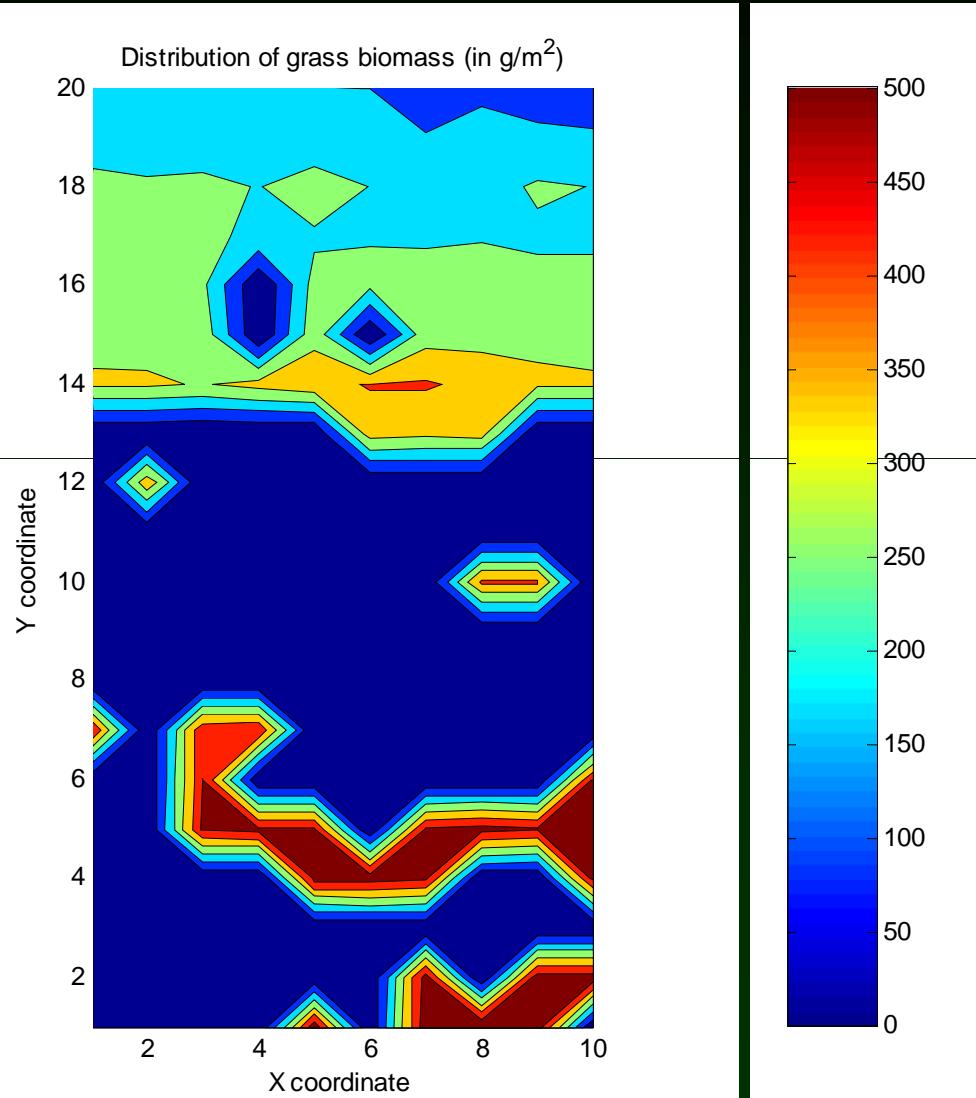
Grass biomass



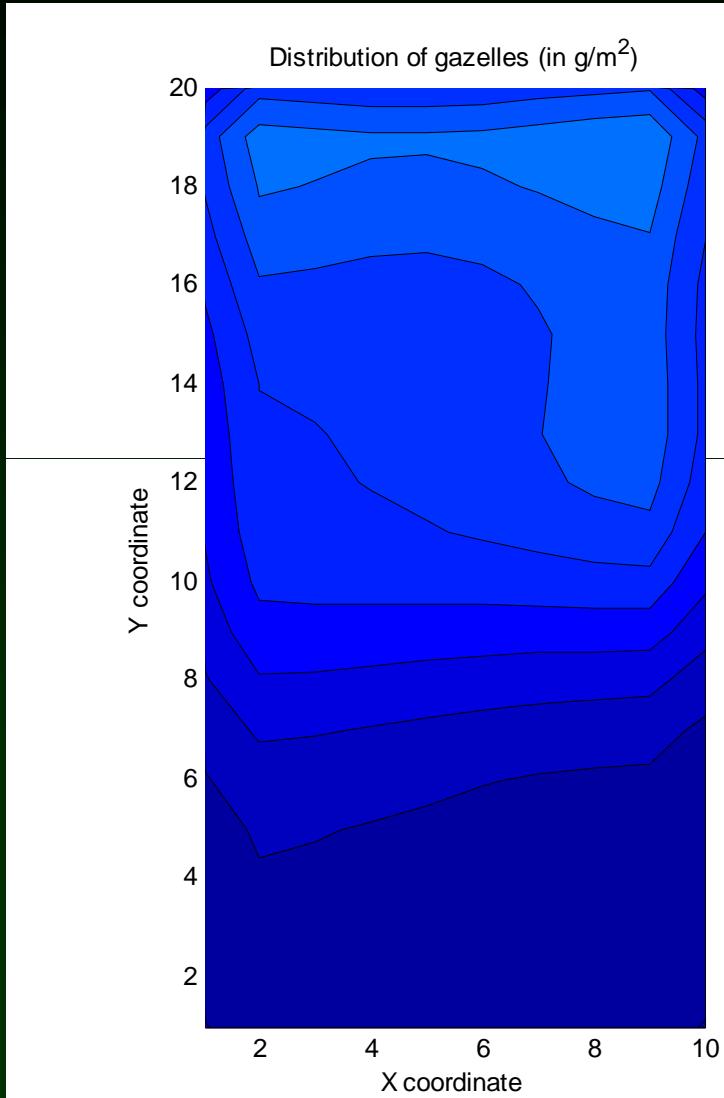
Thomson's gazelles



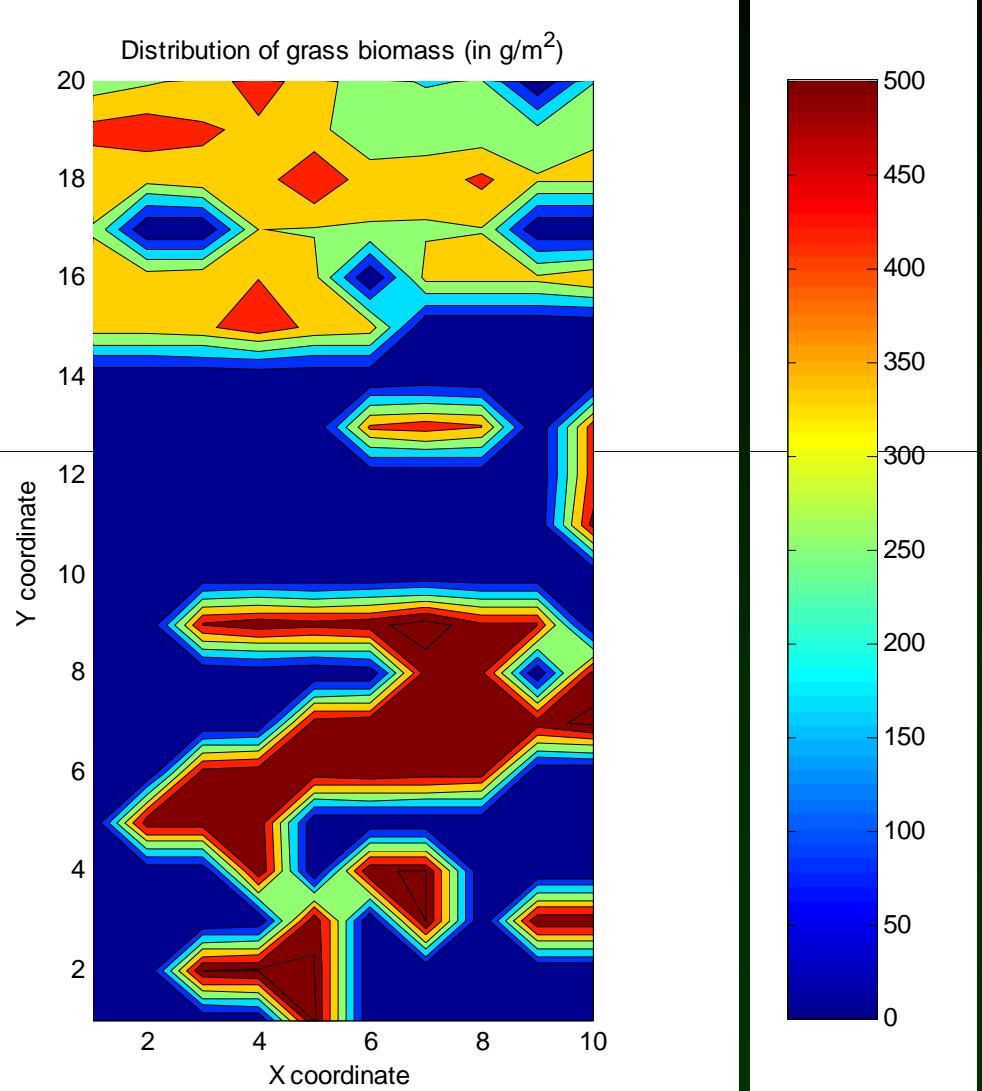
Grass biomass



Thomson's gazelles



Grass biomass



Conclusions

- Group formation is stabilizing
- Predator group formation lends density-dependence
- Management actions should encourage natural grouping patterns, to improve probability of persistence
- Interaction between social and spatial structure has implications for predator-prey dynamics