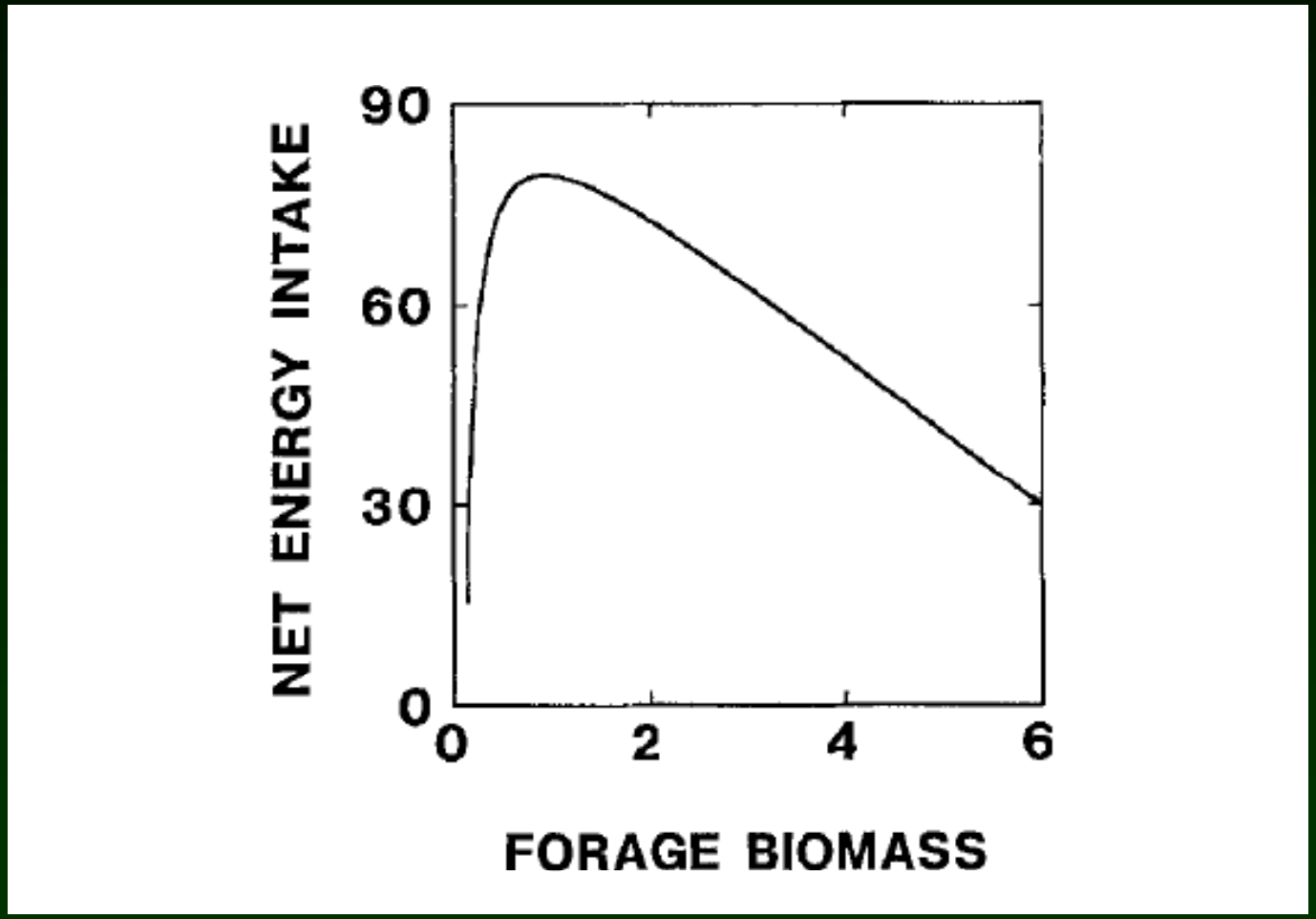
Evolution of migration in a changing world

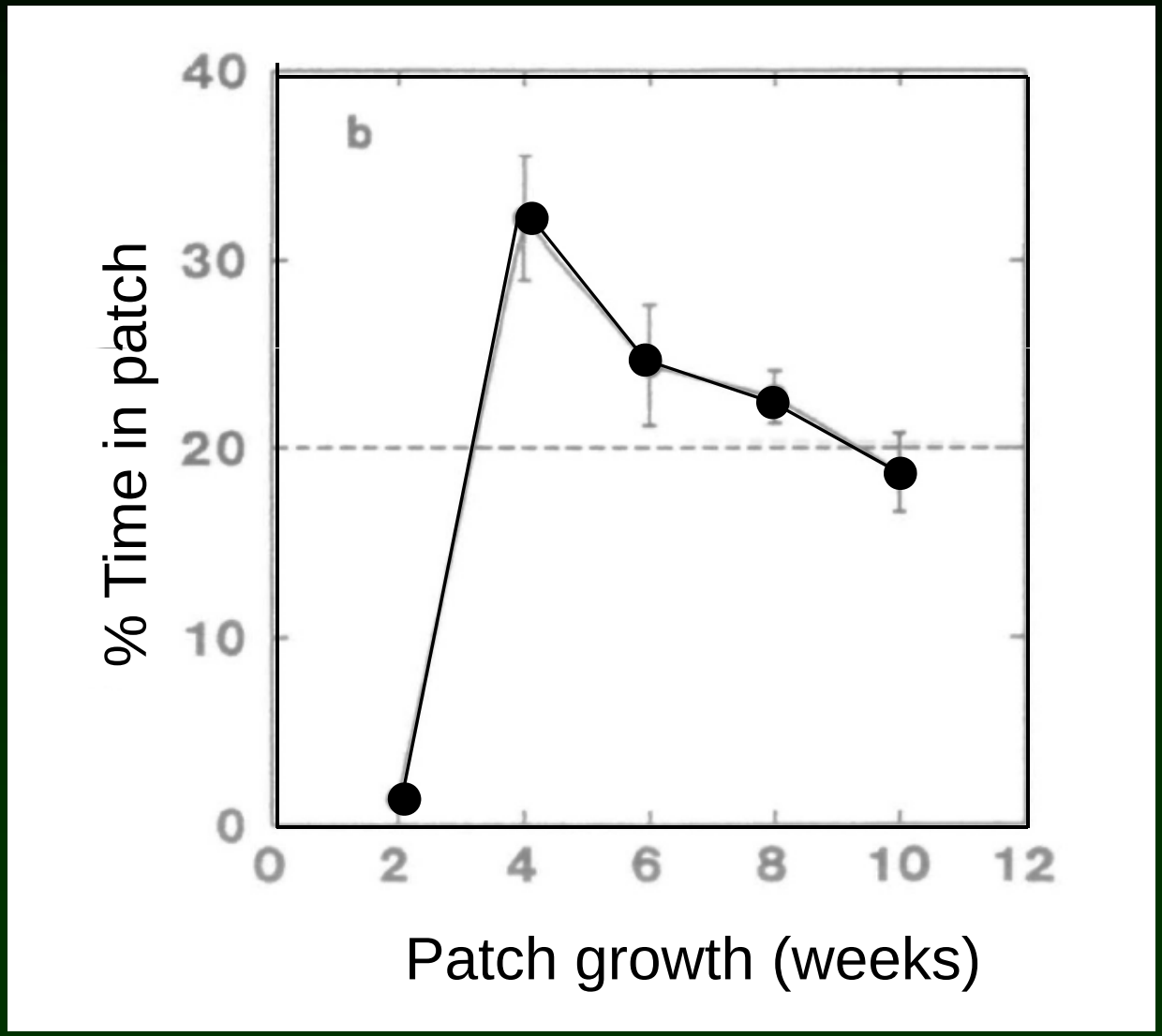
Cervus elaphus (known as red deer, elk, or wapiti)

Rates of energy gain by red deer or elk are highest when feeding on young vegetation (2-4 weeks of growth)



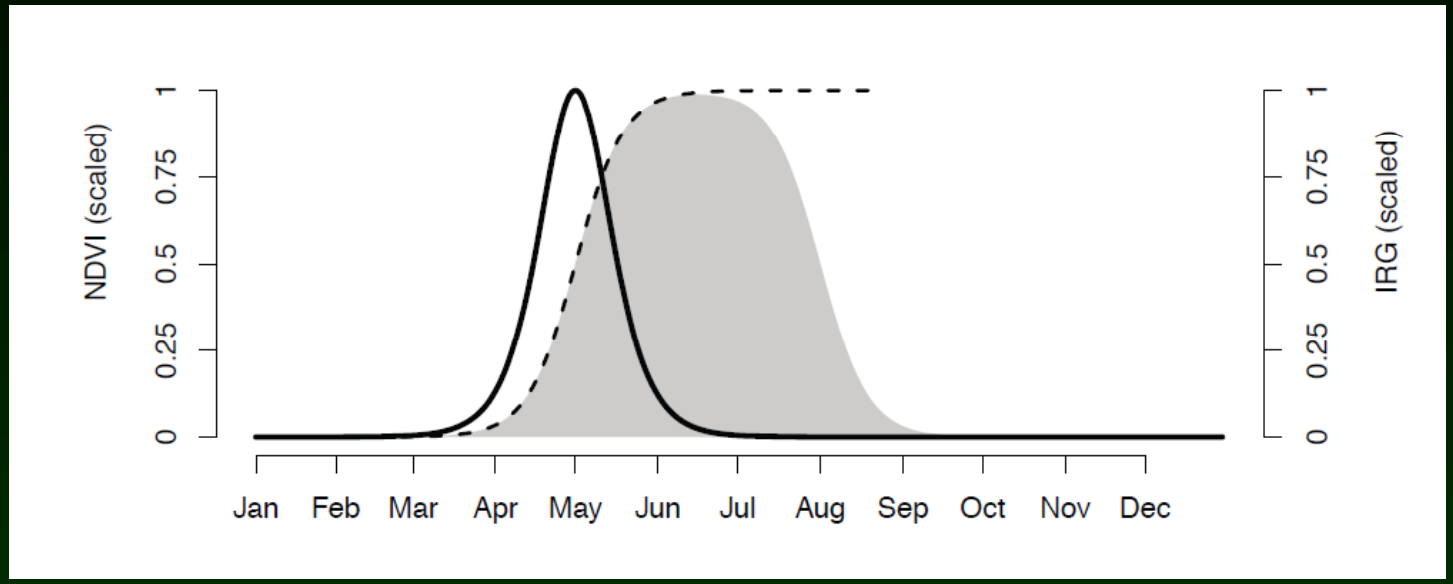
Wilmshurst and Fryxell (1995) Oecologia 104:297-300

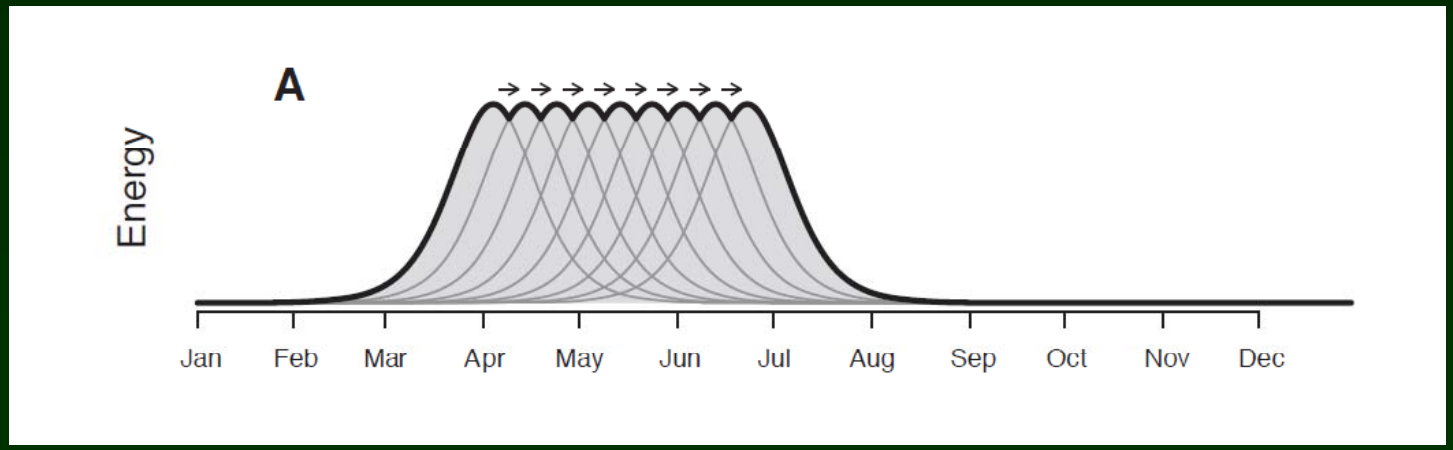
Given a choice, foragers prefer young patches that yield the highest gain



Wilmshurst, Fryxell, and Hudson (1995) Behavioral Ecology 6:209-217

By migrating up elevation gradient, elk could increase energy gain over growing season





Bischof et al. (2012) Am. Nat. 180:407-424

Coupled lattice grazing model:

resource growth

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

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

Coupled lattice grazing model:

functional response

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

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

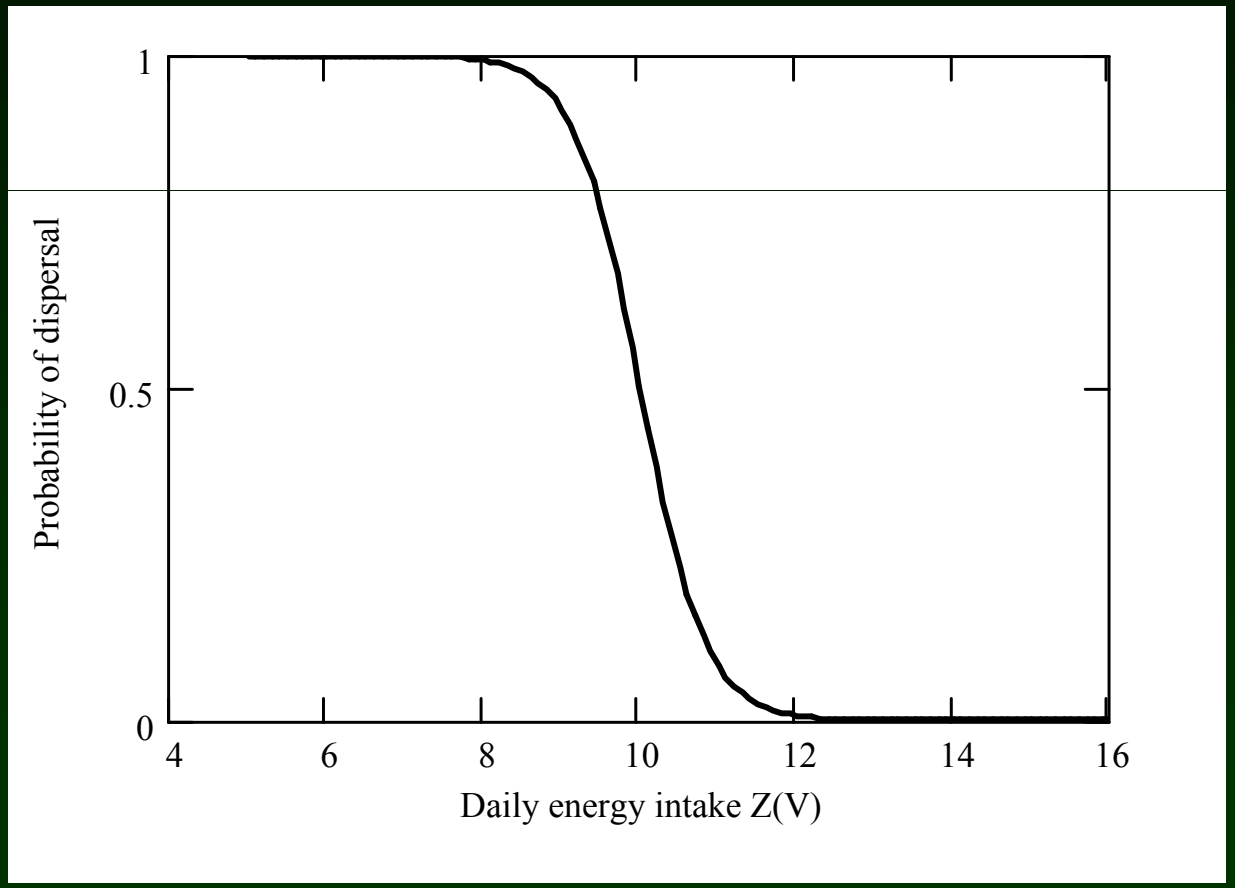
Coupled lattice grazing model:

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

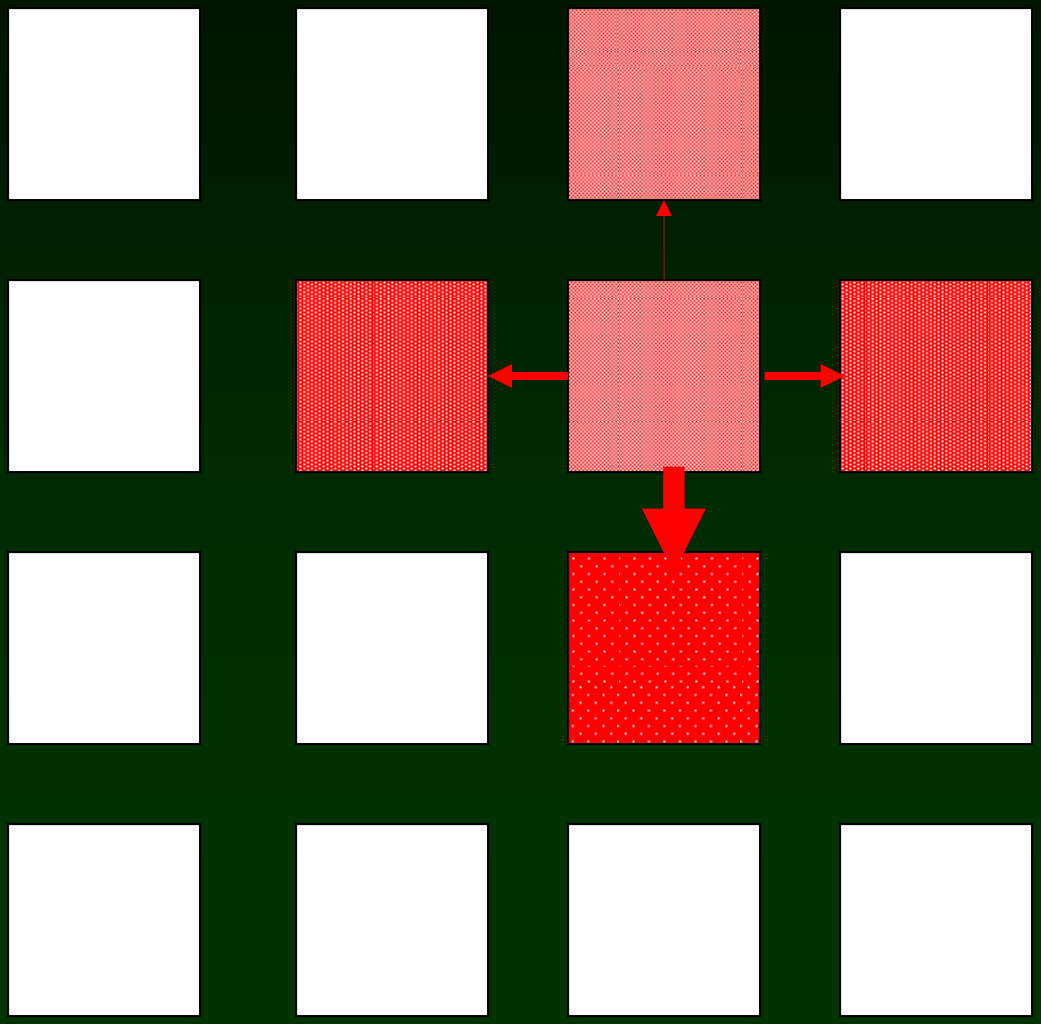
$$\frac{dN_{ij}}{dt} = N_{ij}[\Omega(V_{ij}) - \theta(V_{ij})]$$

spatial response

Adaptive rule: leave patches that are below-average, stay in ones that are above-average

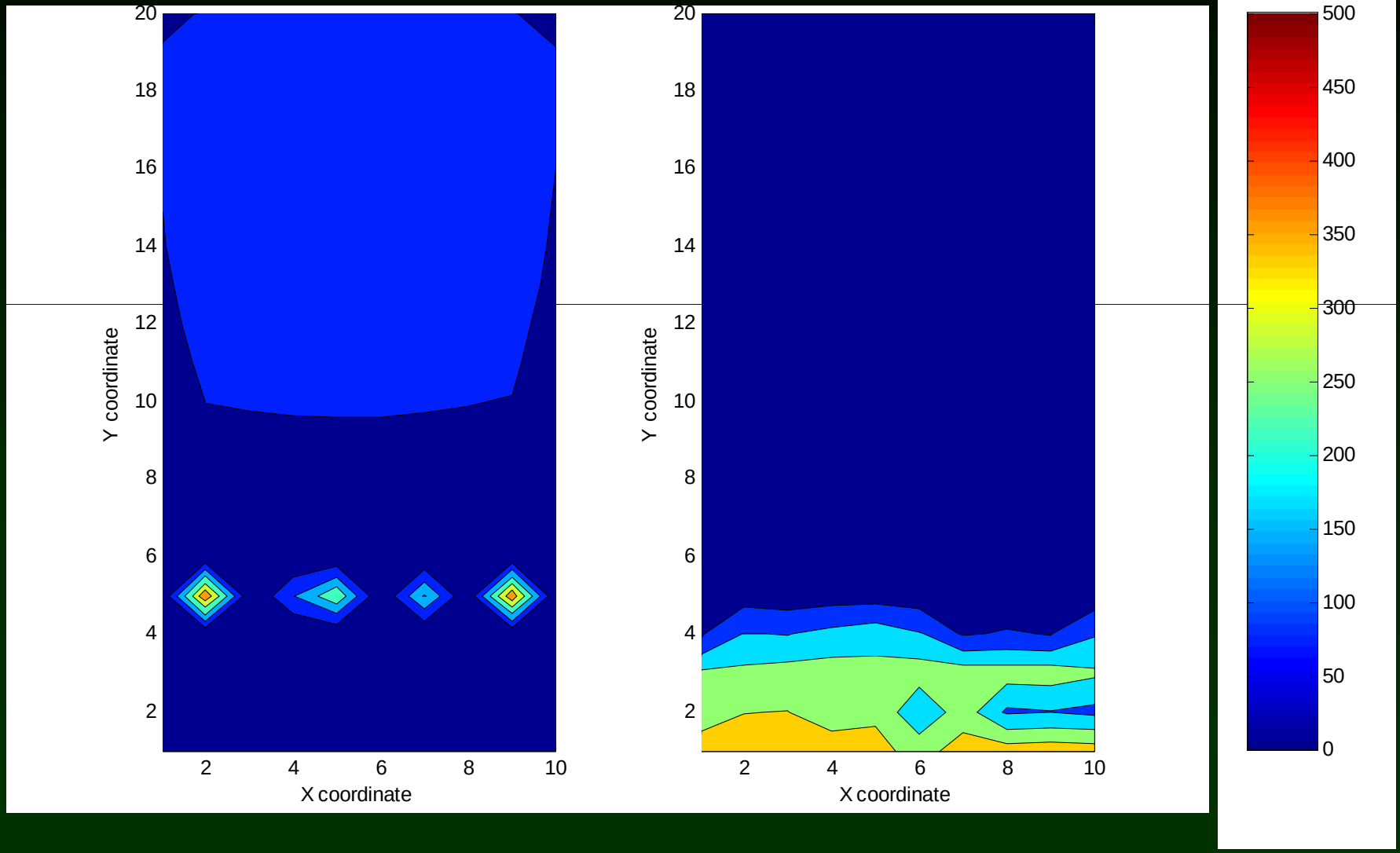


Grazer movement choices match relative energy gain in neighboring patches



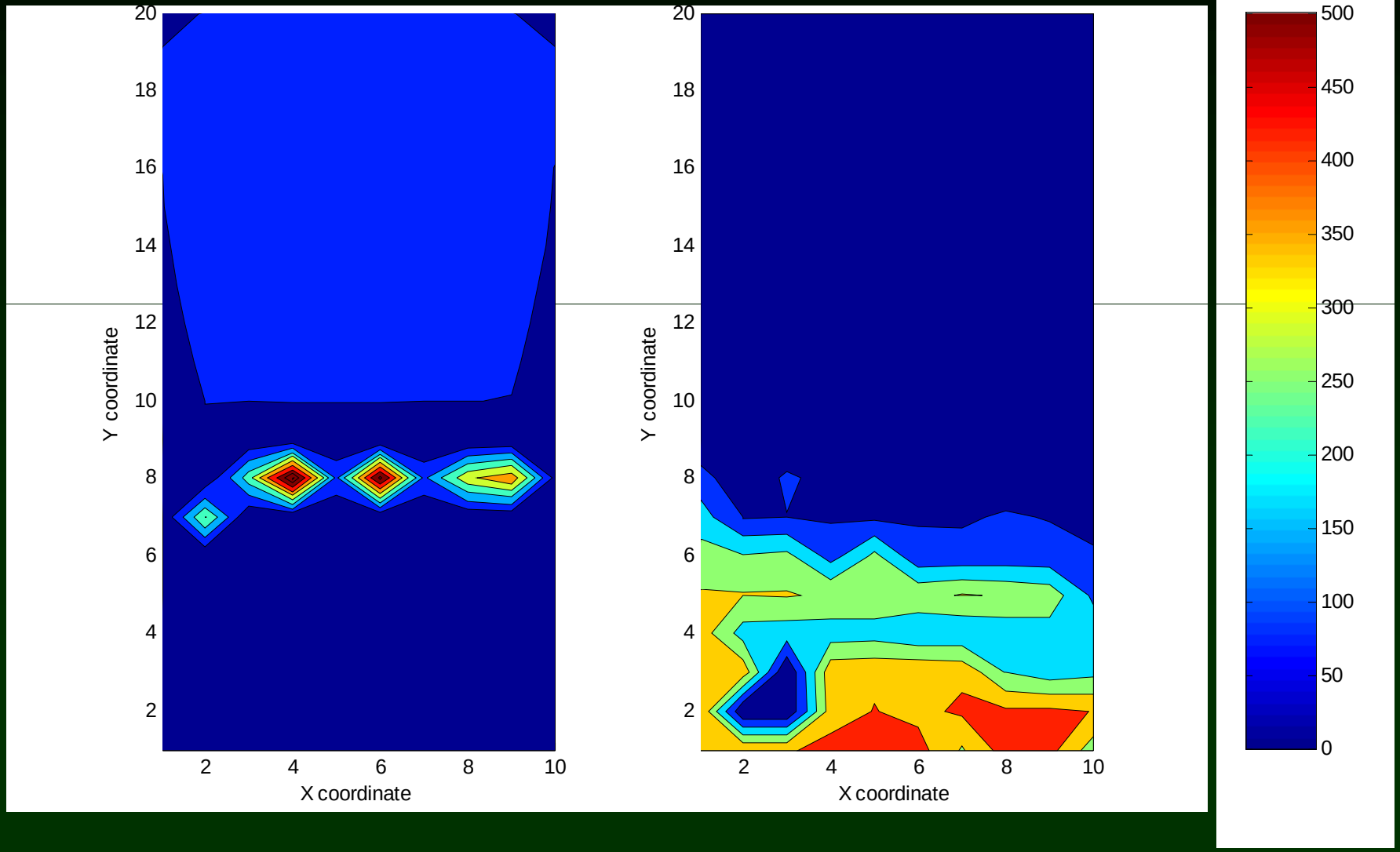
Herbivores

Plant biomass



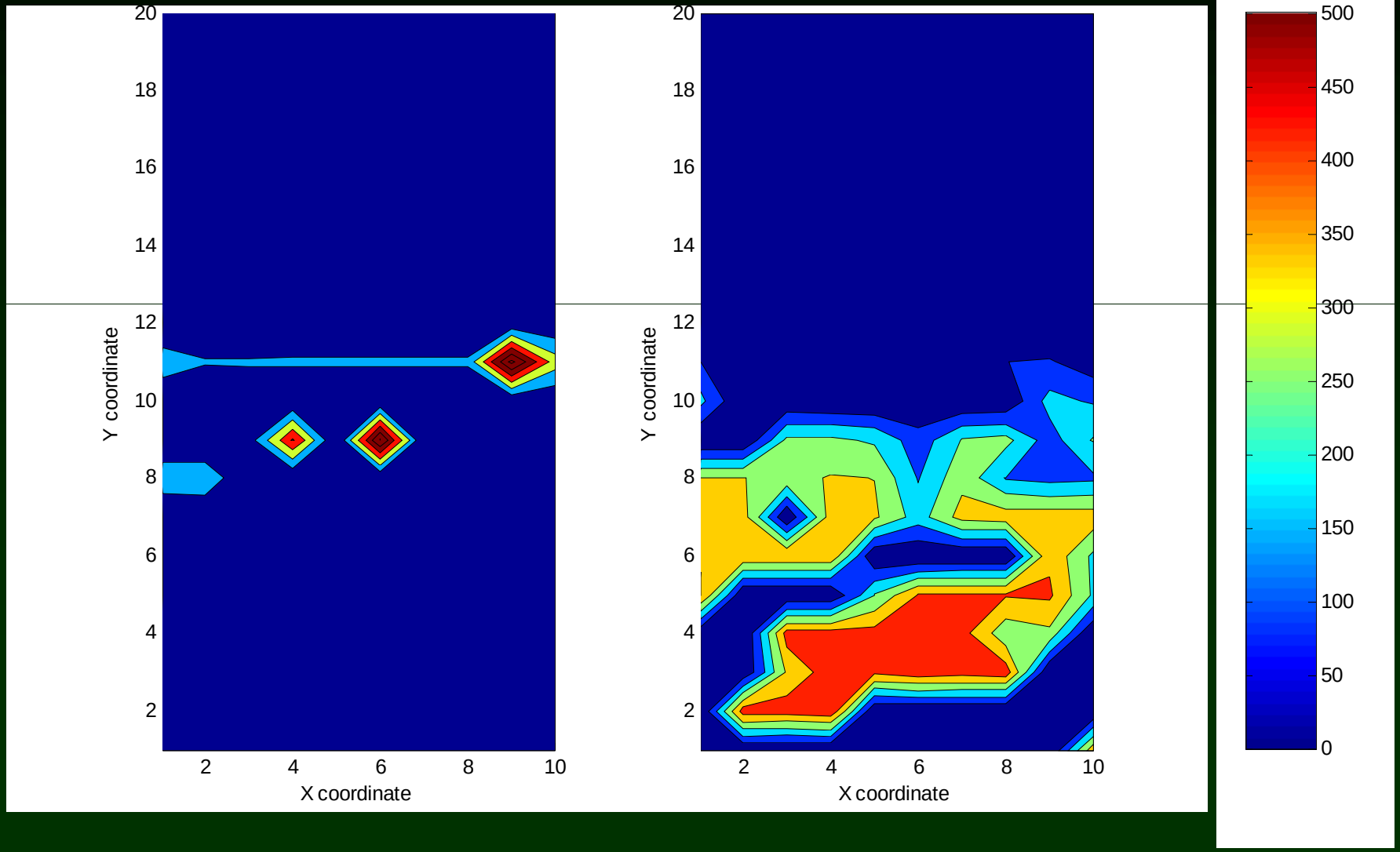
Herbivores

Plant biomass



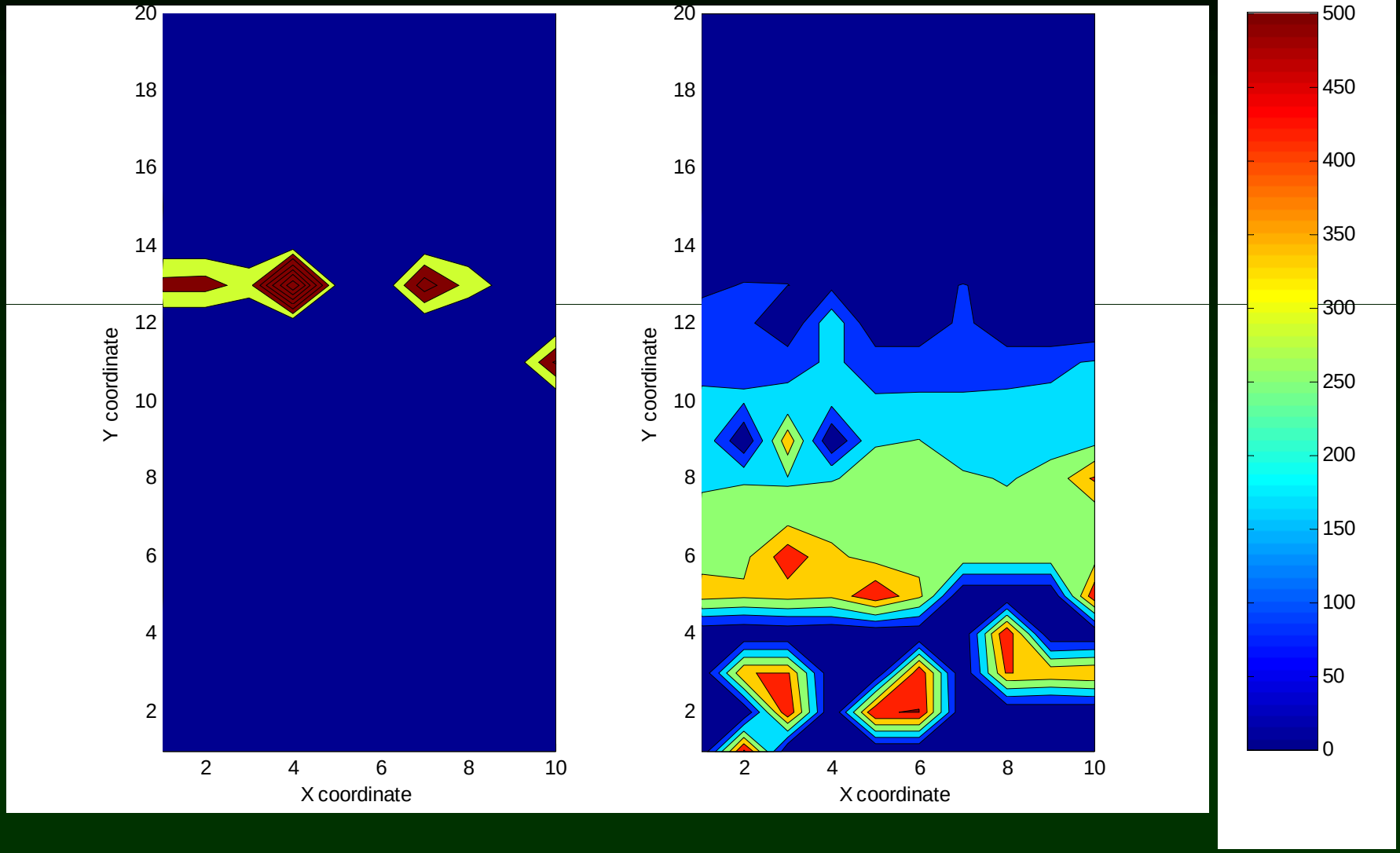
Herbivores

Plant biomass



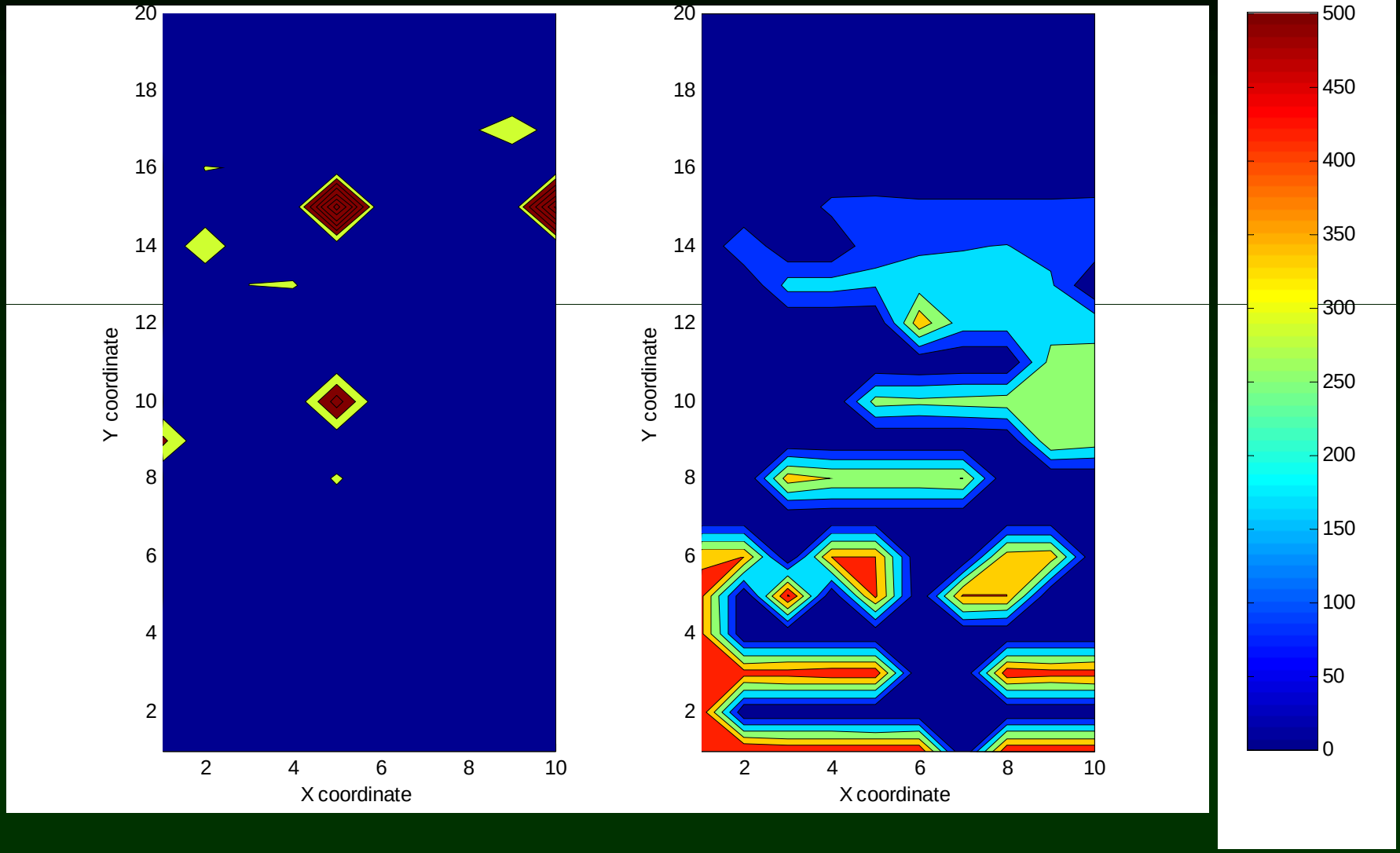
Herbivores

Plant biomass



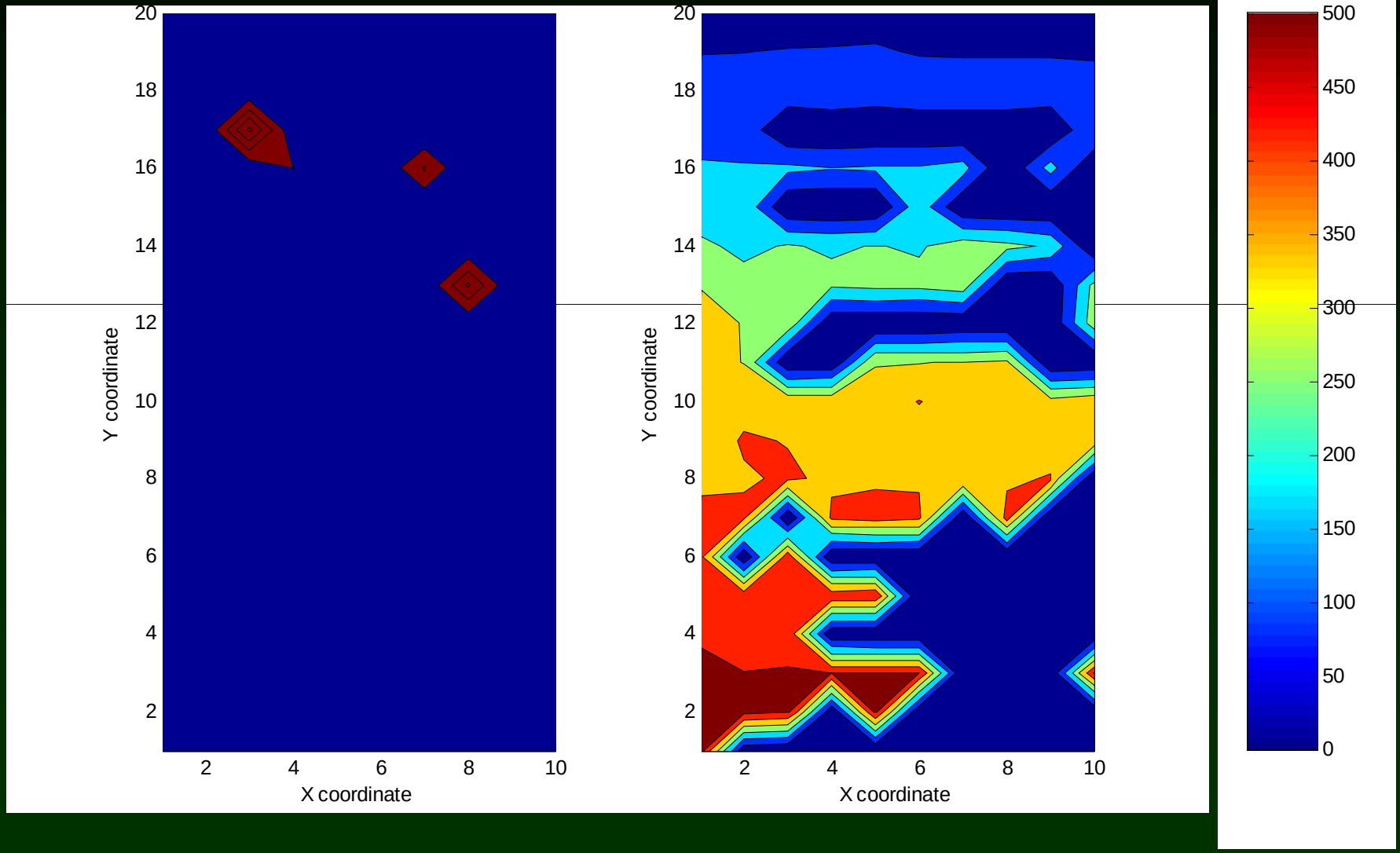
Herbivores

Plant biomass



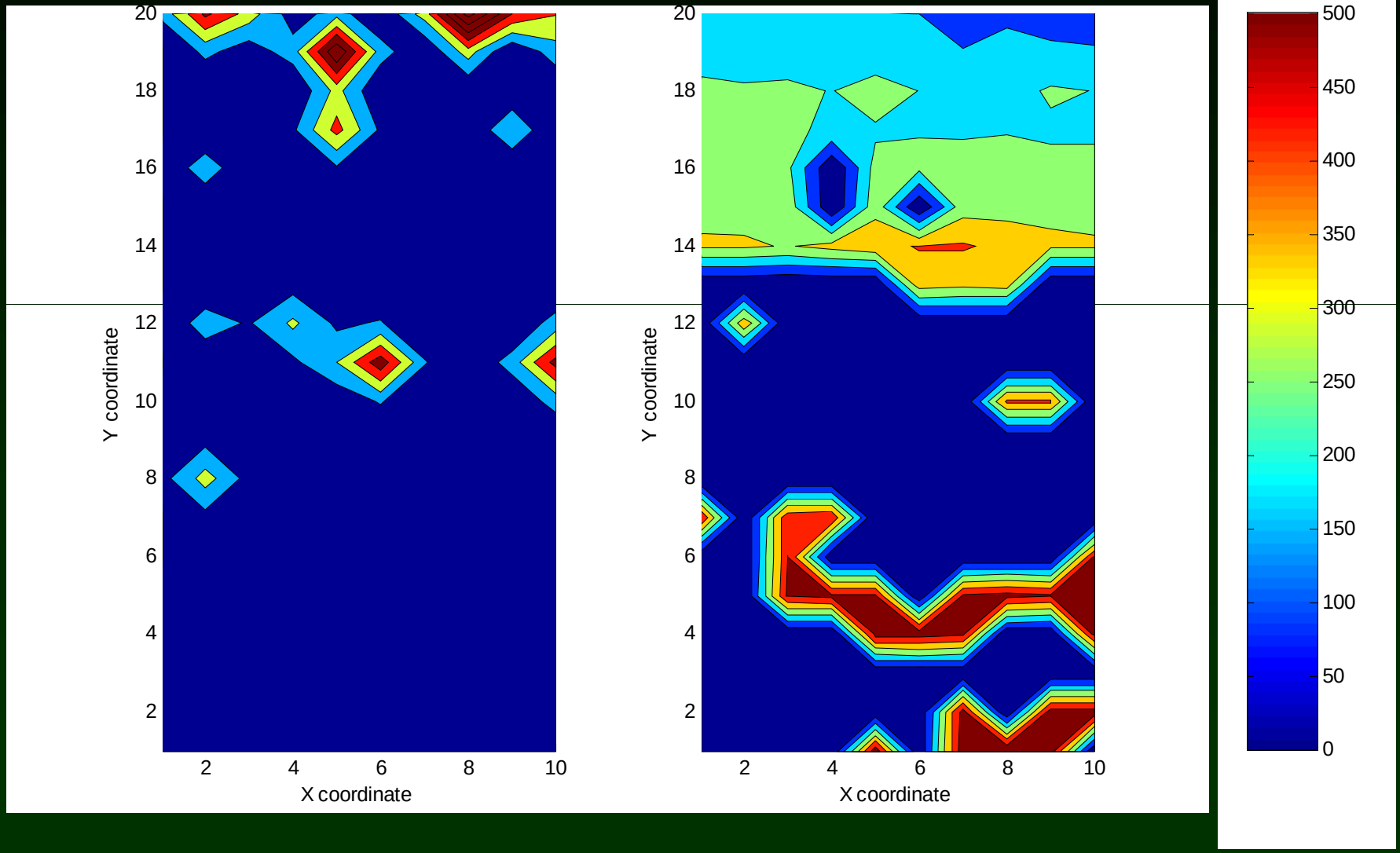
Herbivores

Plant biomass



Herbivores

Plant biomass



Evolutionary model (2 habitats, 2 seasons)

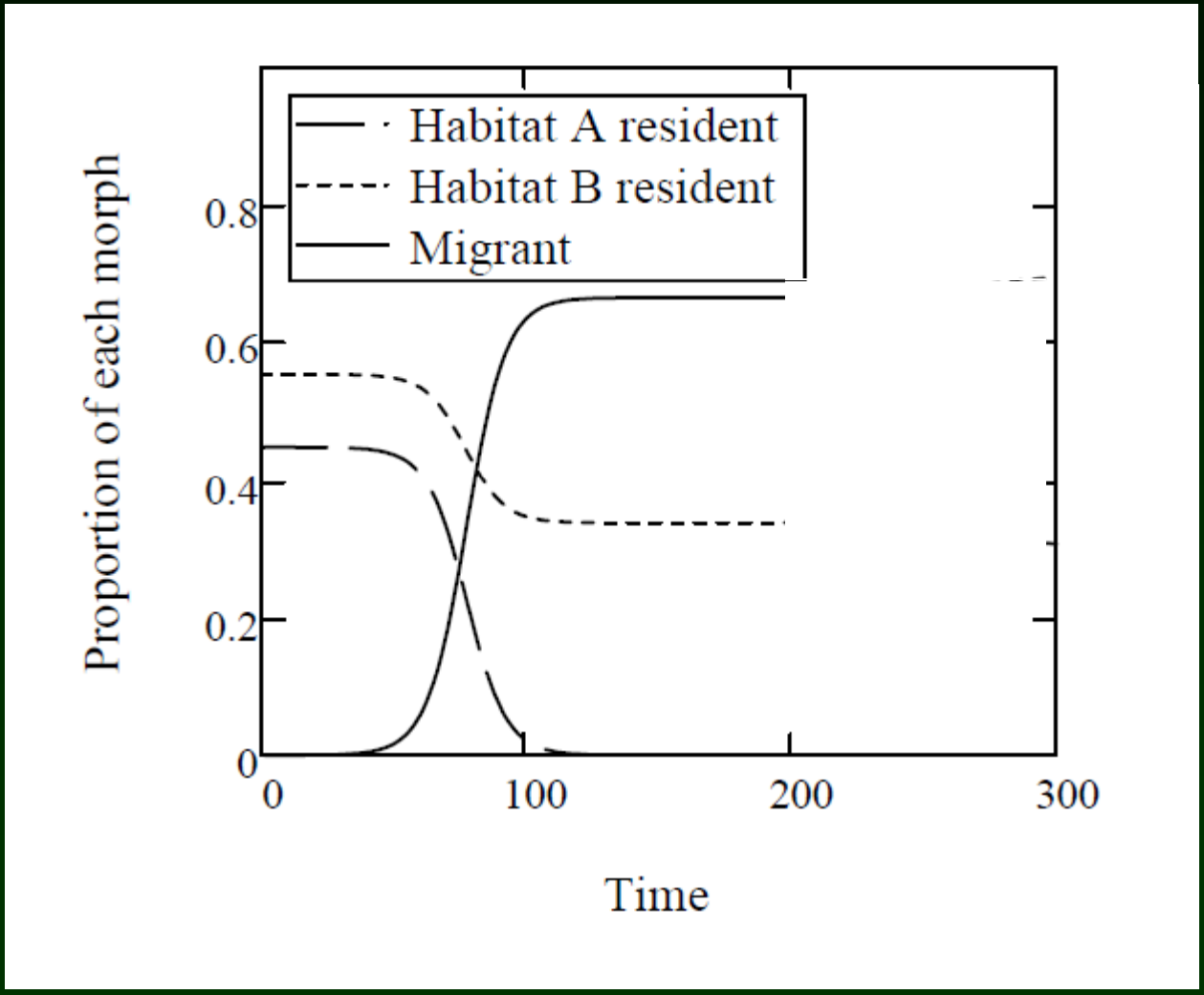
- Lowland (A) resident
- Highland (B) resident
- Migrant

$$N1(t+1) = N1(t) \cdot \exp(r_A \cdot [1 - N1(t) - N3(t)] - s_A)$$

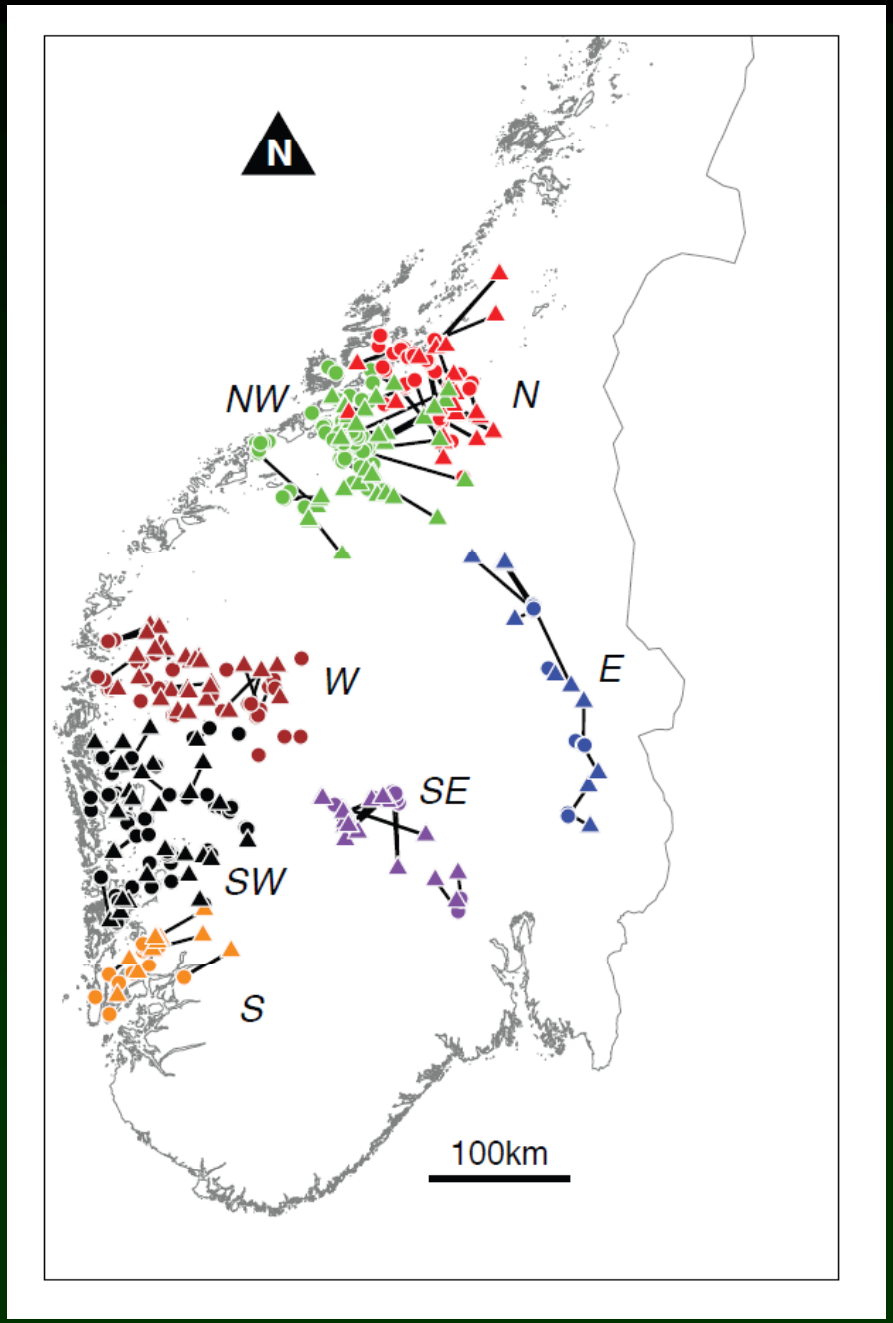
$$N2(t+1) = N2(t) \cdot \exp(r_B \cdot [1 - N2(t)] - s_B)$$

$$N3(t+1) = N3(t) \cdot \exp(r_A \cdot [1 - N1(t) - N3(t)] - c - s_B)$$

Partial migration is an ESS so long as both habitats are sources…



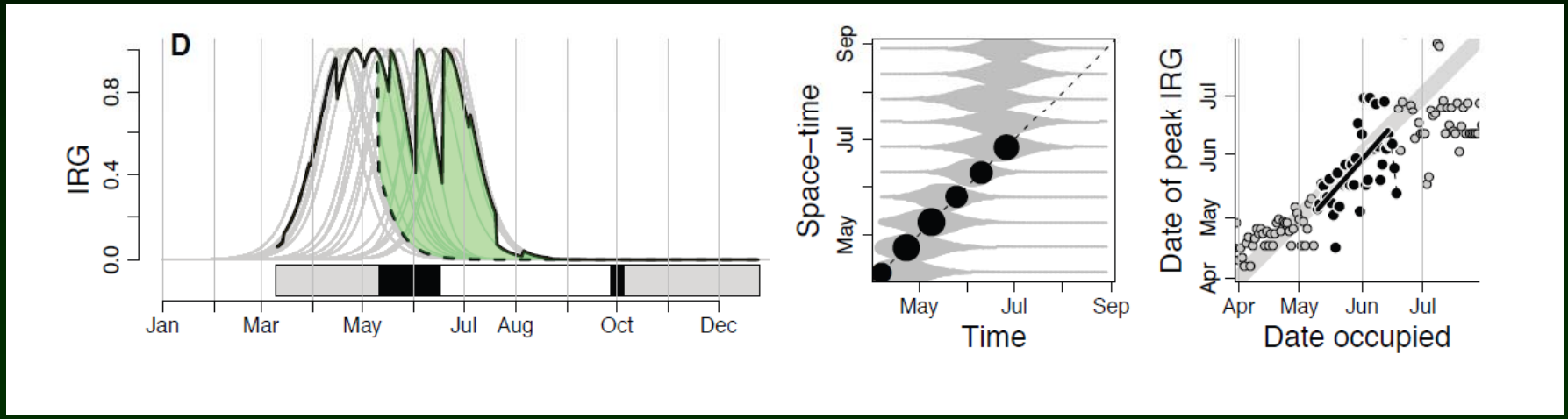
Fryxell and Holt (2012) Ecology



There is a lot of variation in movement behavior of red deer across different parts of Norway

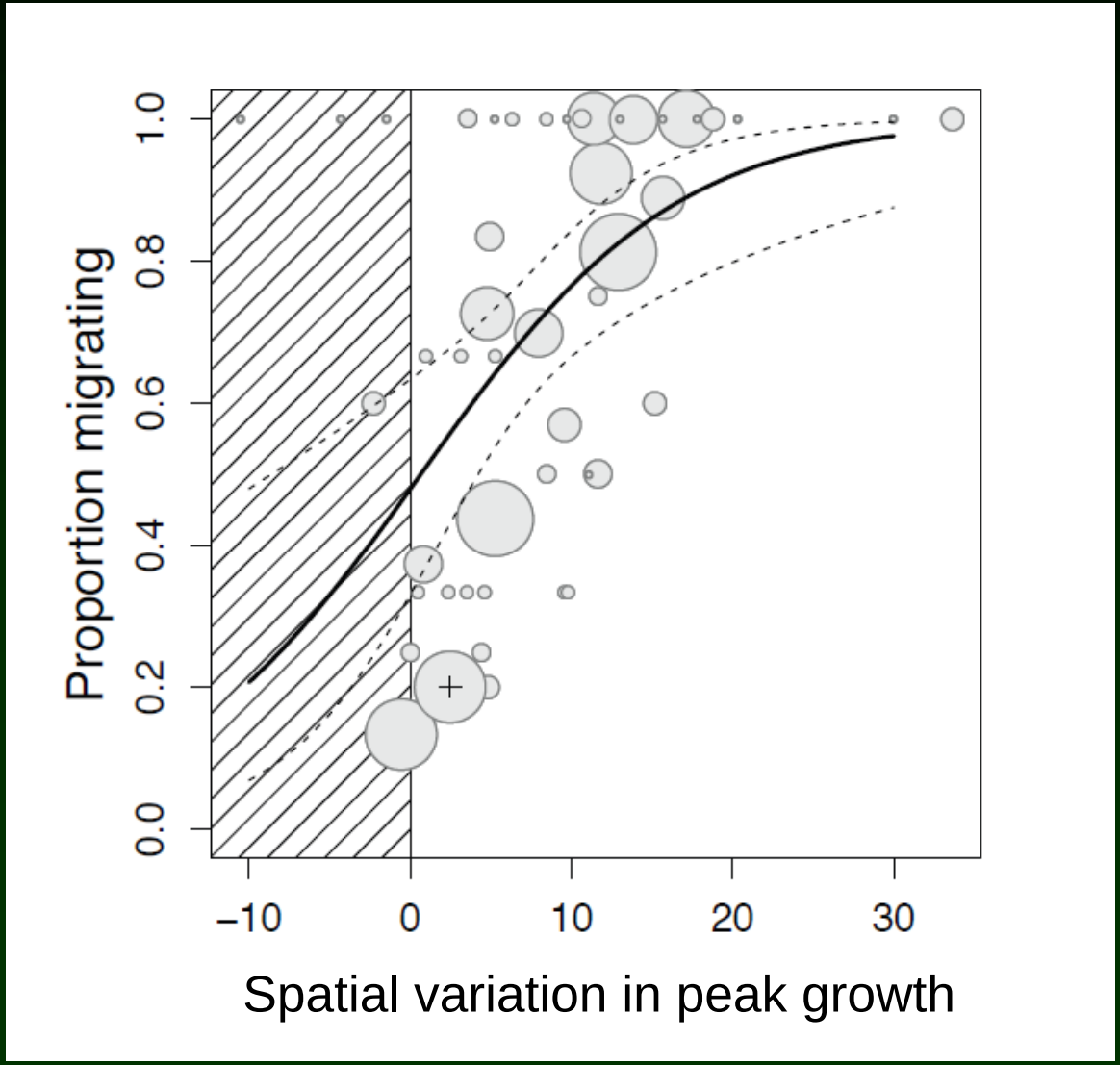
Bischof et al. (2012) Am. Nat. 180:407-424

Where there is substantial elevation change, red deer are migratory, tracking the ‘green wave’



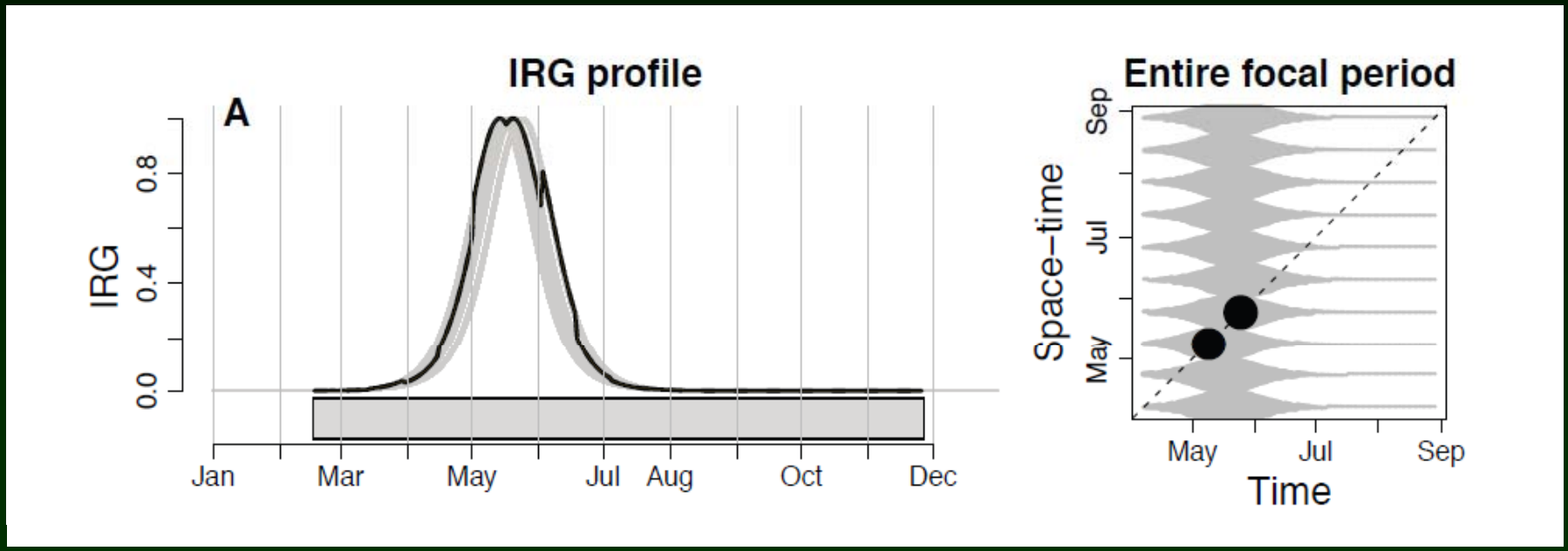
Bischof et al. (2012) Am. Nat. 180:407-424

Partial migration is common, becoming more pronounced where there is less heterogeneity in ‘green wave’



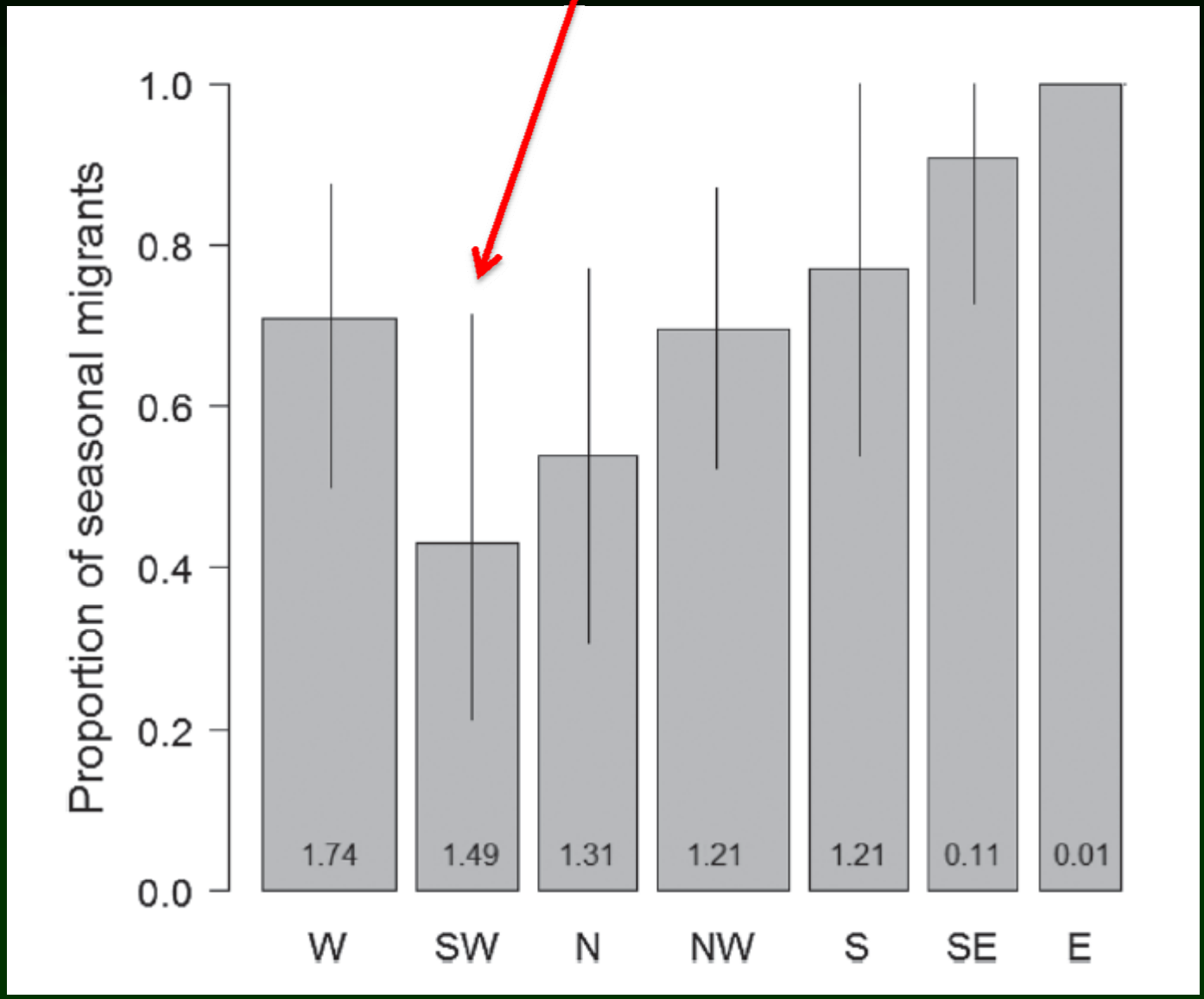
Bischof et al. (2012) Am. Nat. 180:407-424

Where there is little elevation change, most red deer are non-migratory.



Bischof et al. (2012) Am. Nat. 180:407-424

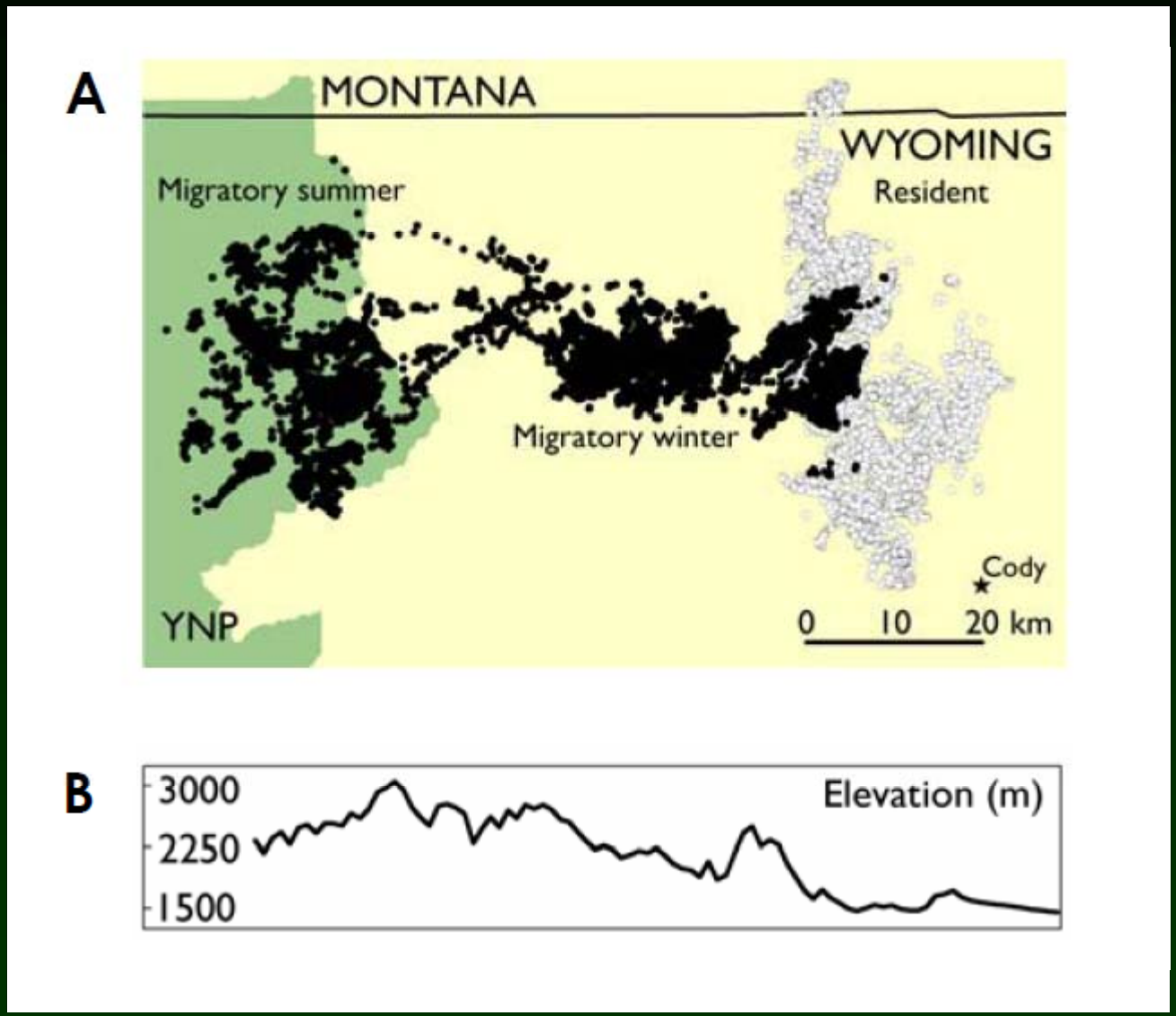
Partial migration is also pronounced where red deer density is high



Bischof et al. (2012) Am. Nat. 180:407-424

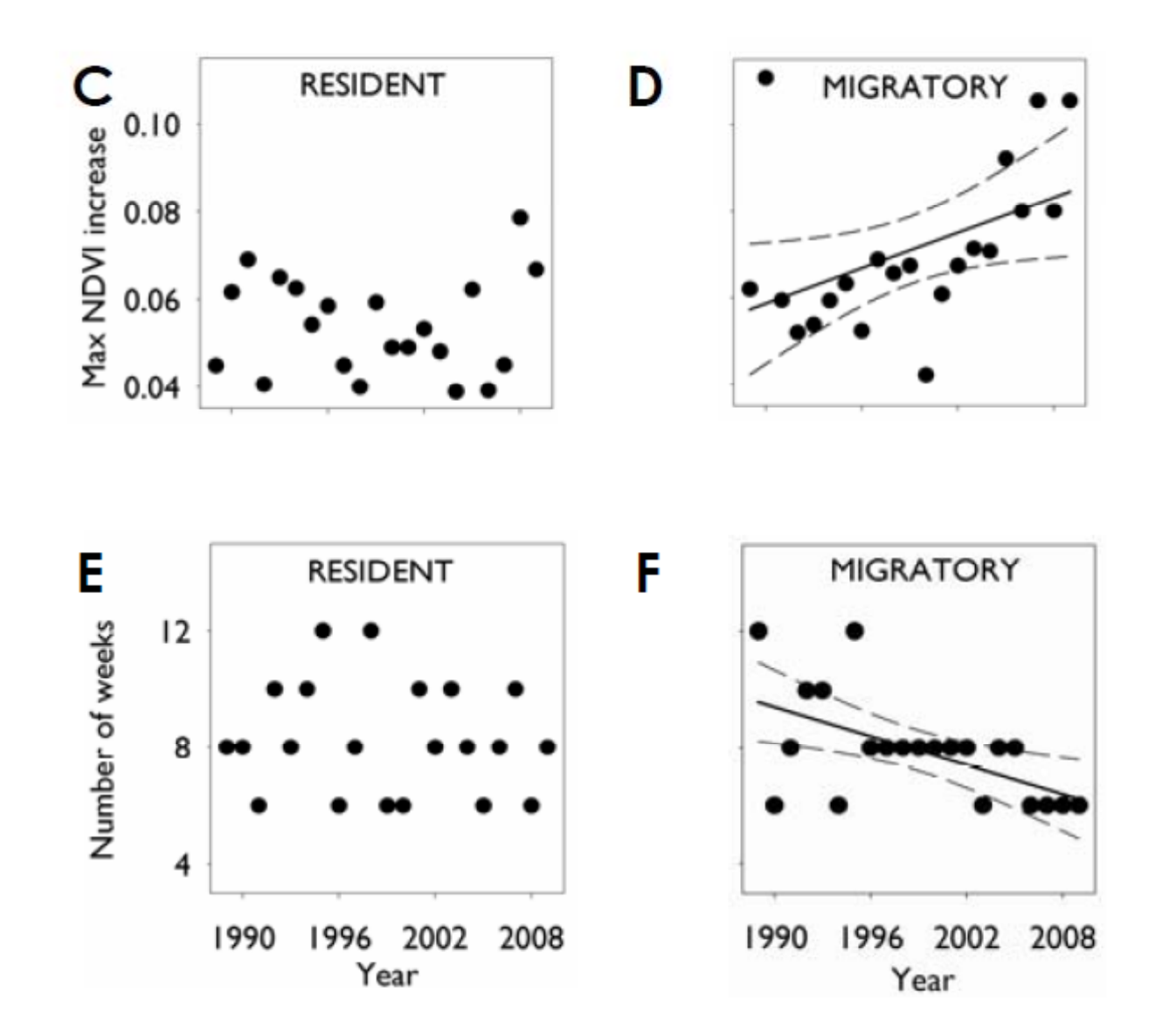
What might be the consequences of environmental change for migration?

-Habitat decline



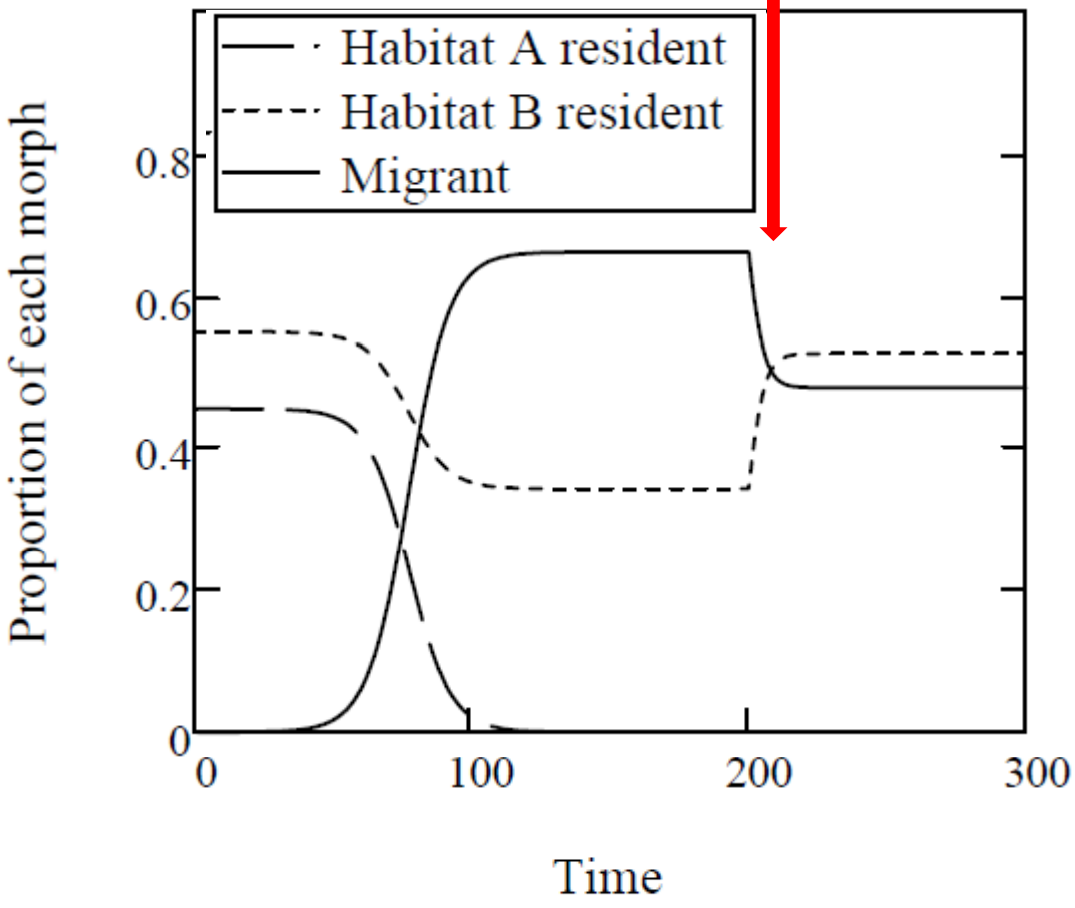
Middleton et al. (2012) Ecology in press

In recent years green up is more intense and much faster



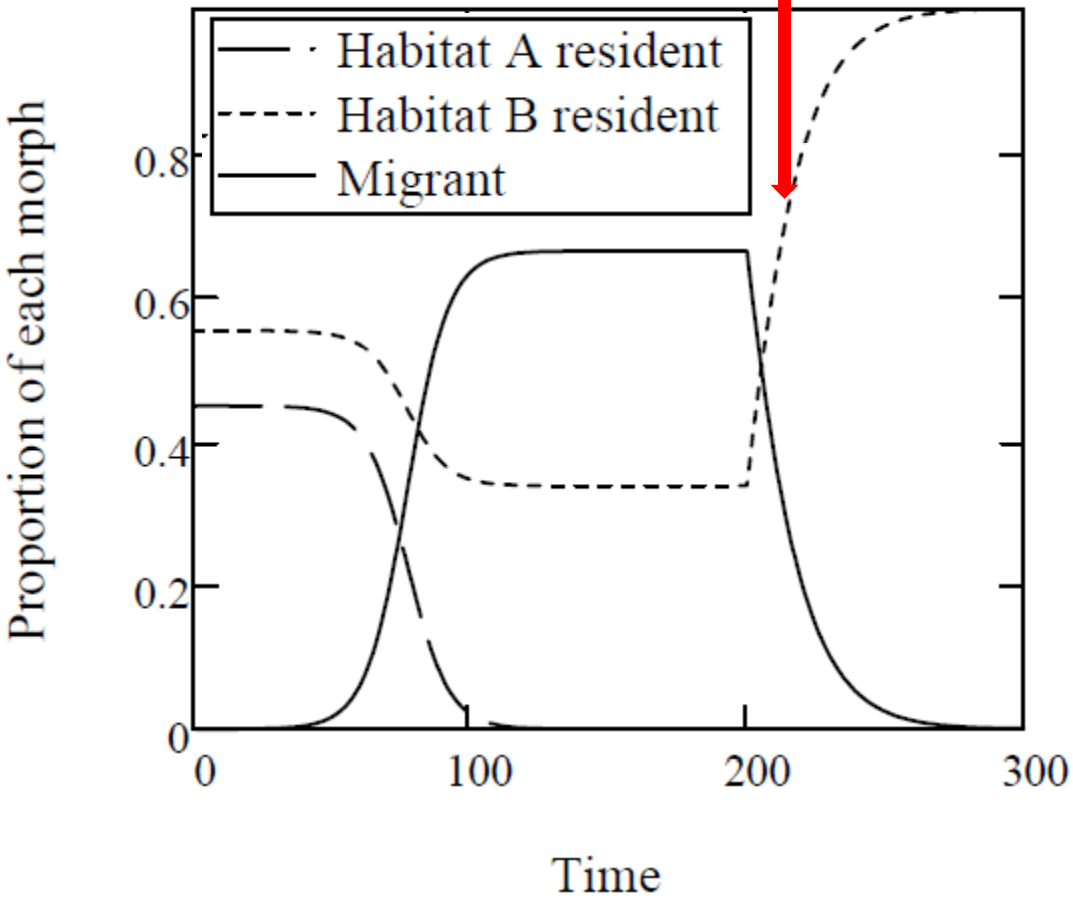
Middleton et al. (2012) Ecology in press

slight decline in habitat B



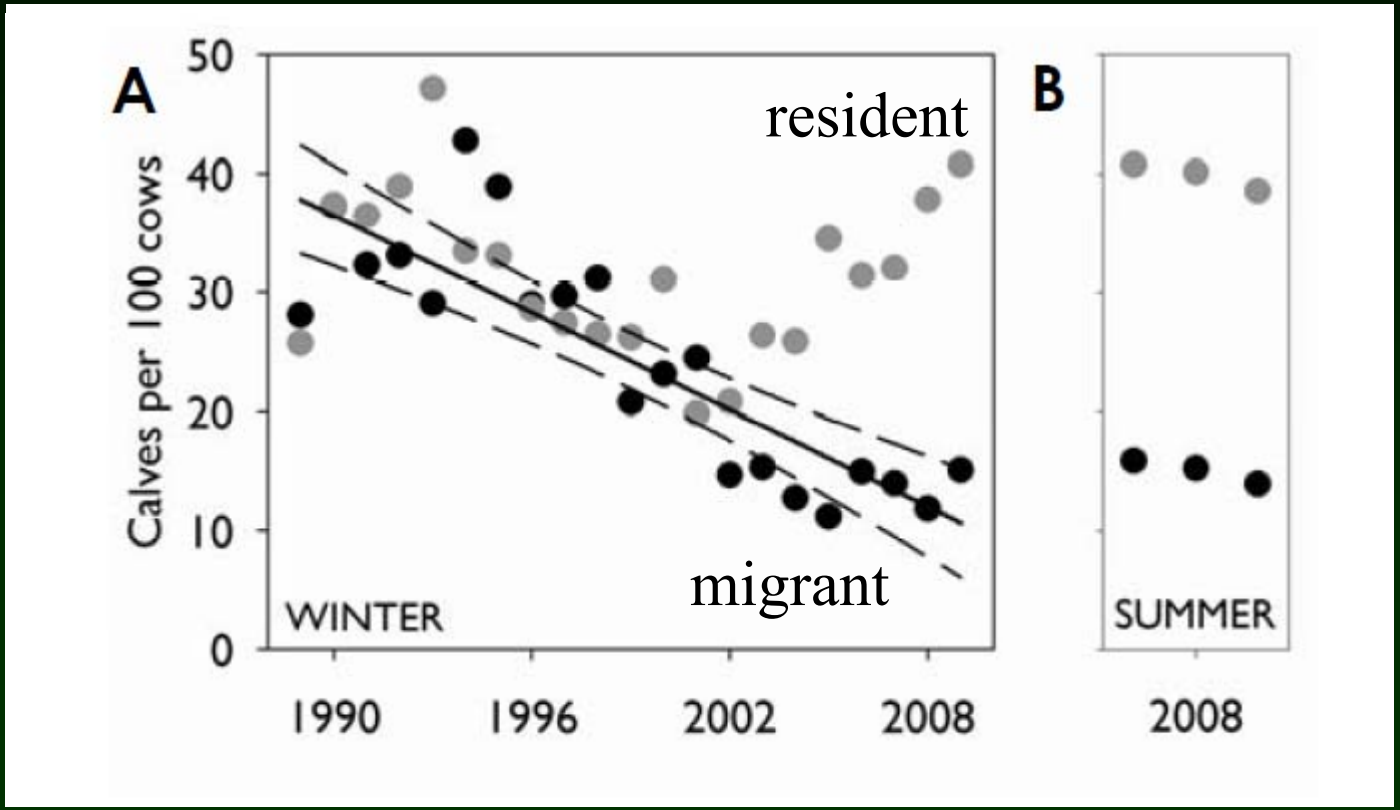
Fryxell and Holt (2012) Ecology

large decline in habitat B



Fryxell and Holt (2012) Ecology

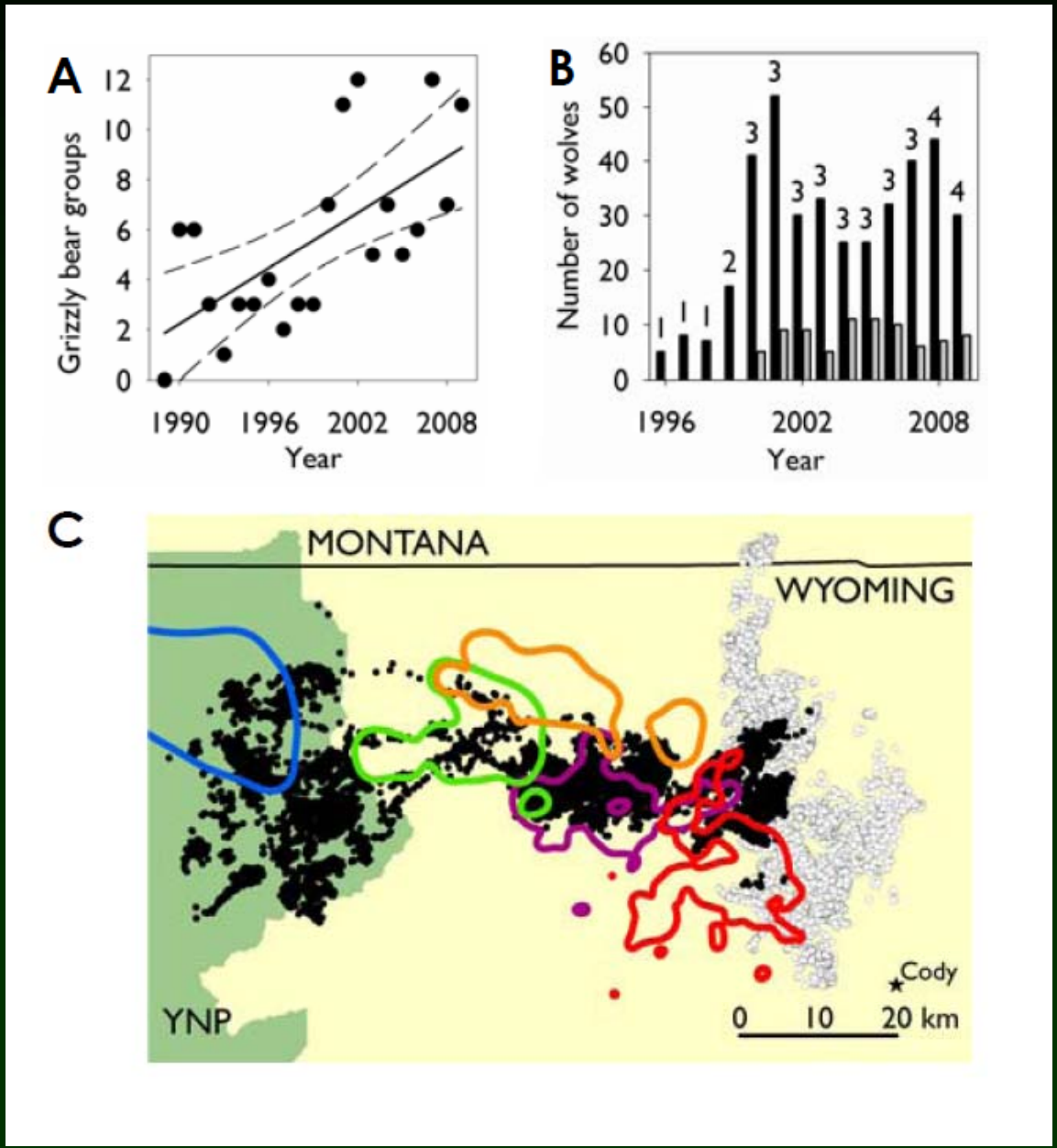
More rapid green-up is associated with declining recruitment



What might be the consequences of environmental change for migration?

-Habitat decline
-Increased cost of migration

Migrants also face growing wolf and bear populations



Middleton et al. (2012) Ecology in press

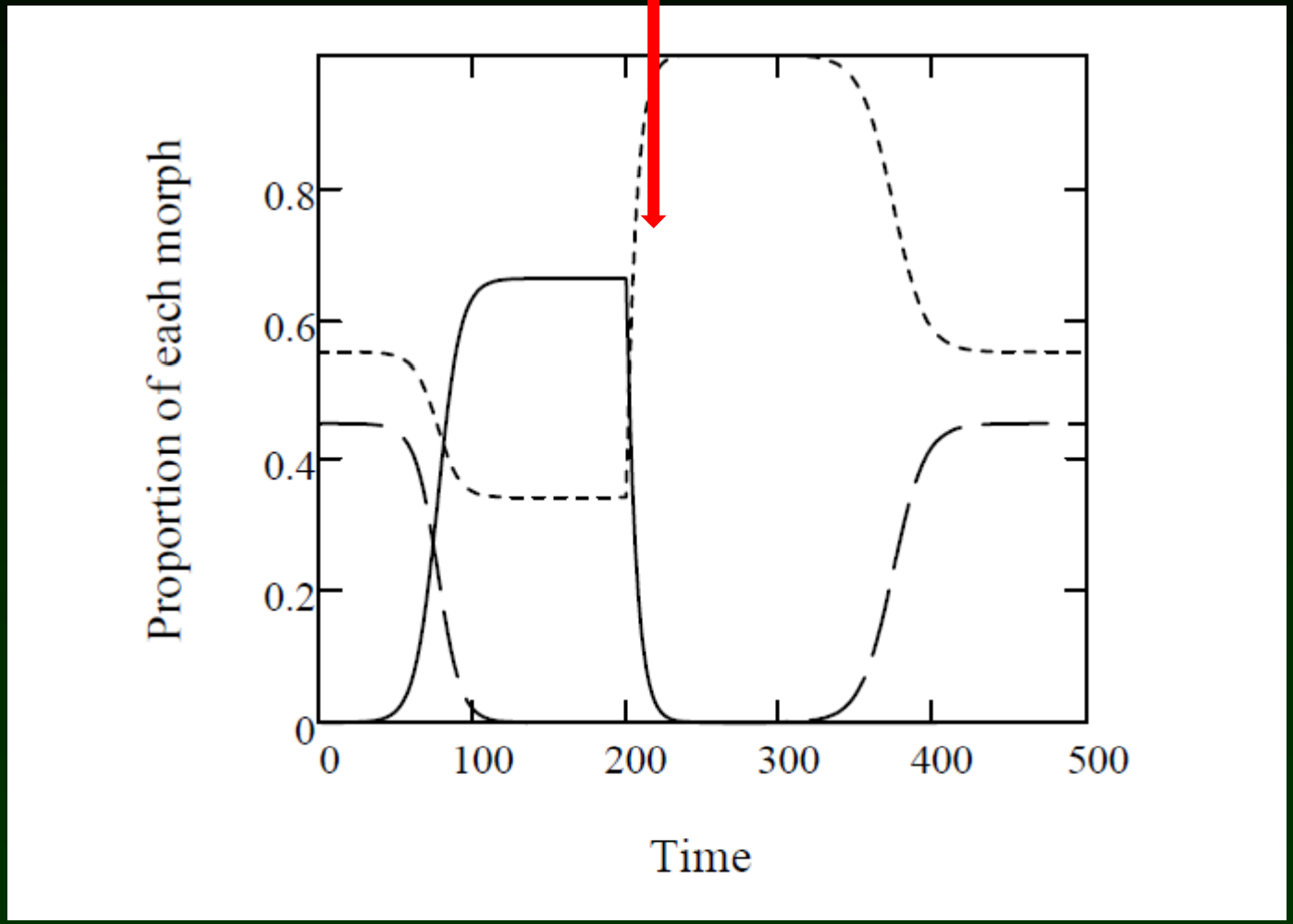
Elk survival in Alberta (migrants vs residents)

Table 2. Mean annual cause-specific mortality rates of migrant and resident elk during 2002–2004, Ya Ha Tinda elk population, Banff National Park. SE's calculated via the delta approximation. Harvest includes legal bow and rifle, poaching, and treaty First Nations harvest. Other includes cougar, coyote and disease.

% Mort	Migrant	SE	Resident	SE
Wolf	0.076	0.010	0.053	0.009
Harvest	0.015	0.004	0.059	0.010
Grizzly	0.046	0.007	0.013	0.004
Other	0.023	0.005	0.013	0.004
	λ=0.88		λ=0.90	

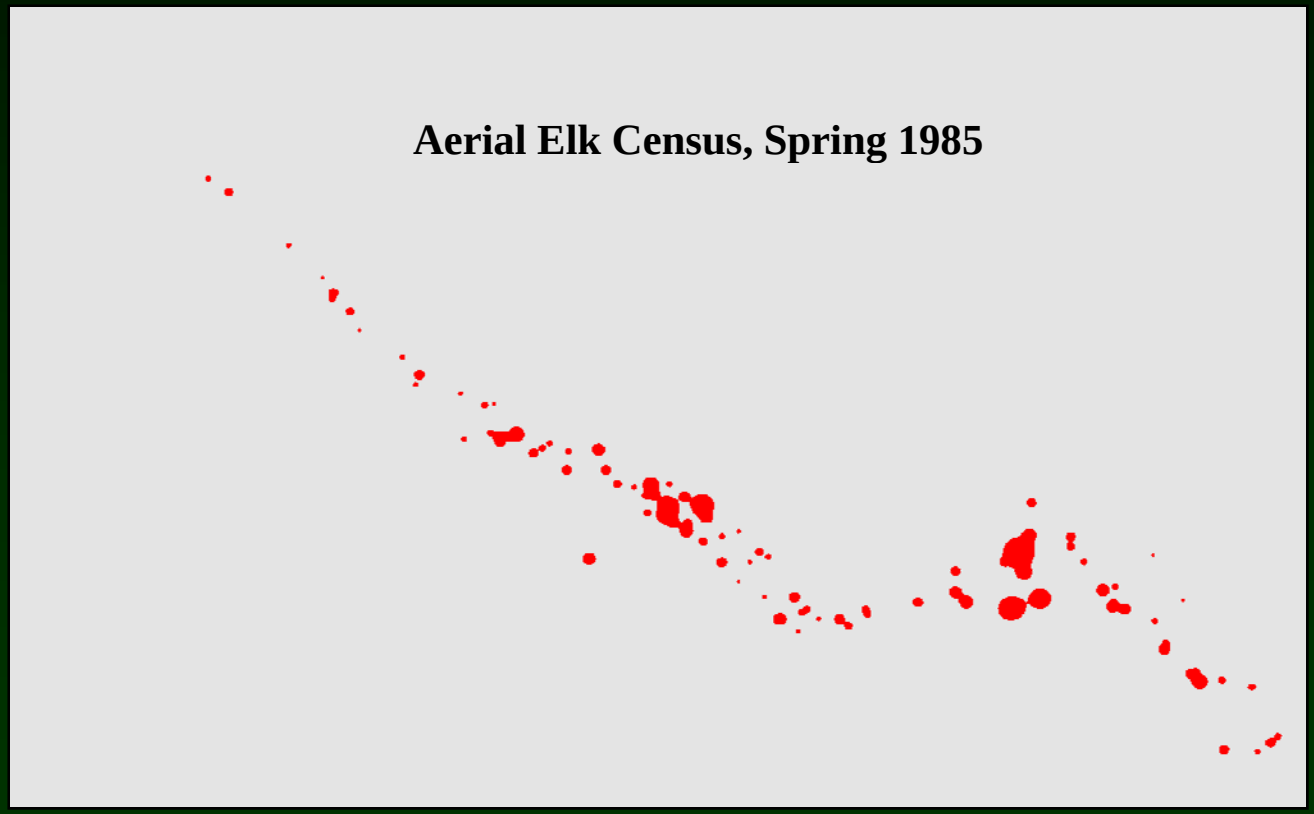
Hebblewhite (2011) Oikos 120:1860-1870

change in cost of migration

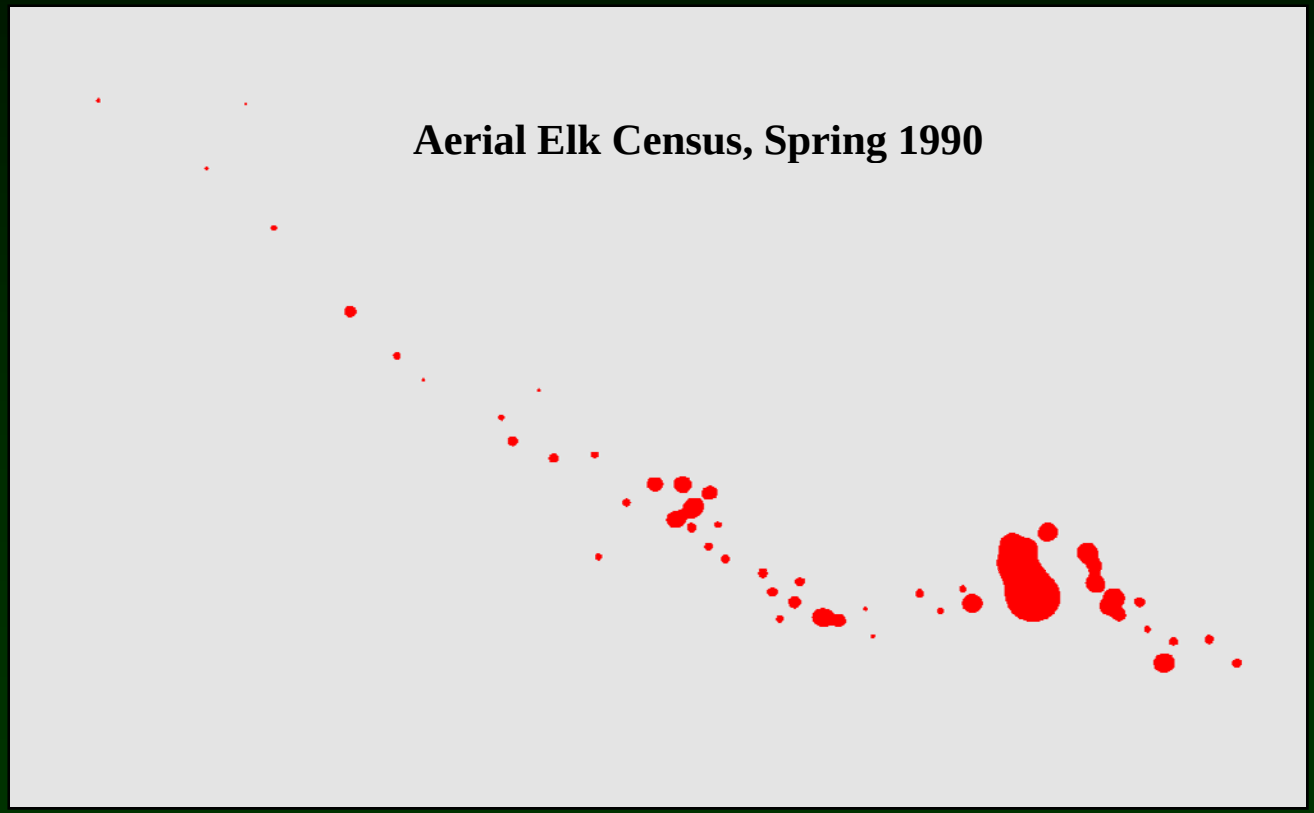


Fryxell and Holt (2012) Ecology

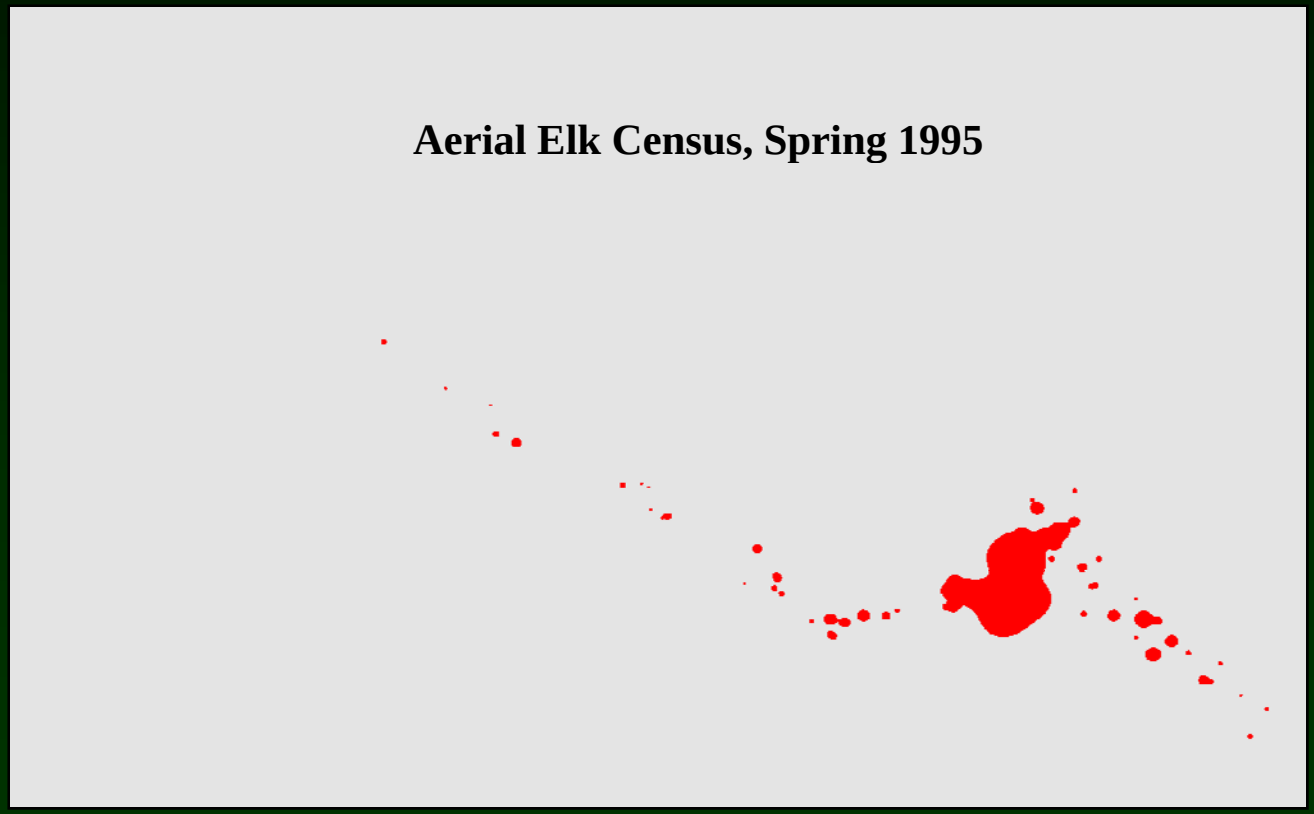
Elk distribution in the Bow Valley (1985)
wolves just arrived… elk still largely migratory



Elk distribution in the Bow Valley (1990)



Elk distribution in the Bow Valley (1995) wolves well established…



and this is what they found so attractive about resident life…

Conclusions

- Partial migration in ungulates has evolved to improve access to heterogeneous resources
- Global climate change is reducing the value of high elevation habitat
- Increased predator densities due to anthromorphic effects is increasing mortality risk to migrants
- Net effect may be partial or complete loss of migratory morphs