Grazing ecology and scaling issues -

a behavioural and modelling approach

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Issues of scale reveal that applying ecological understanding to complex environmental problems requires two kinds of science

- developing an understanding of properties and processes
- assembling that understanding across scales of time and space

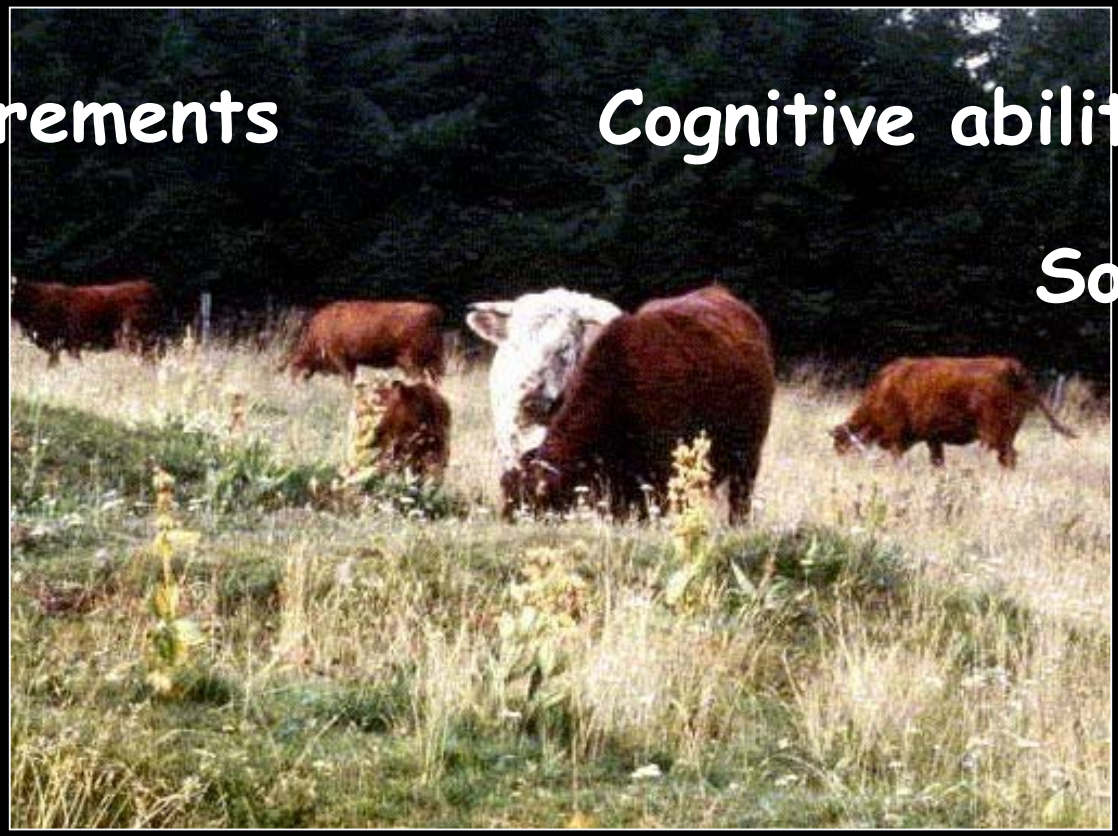
Hobbs 2003 *International Conference on Forest Dynamics and Ungulate Herbivory*

Foraging within a heterogeneous environment

Requirements

Cognitive abilities

Sociability

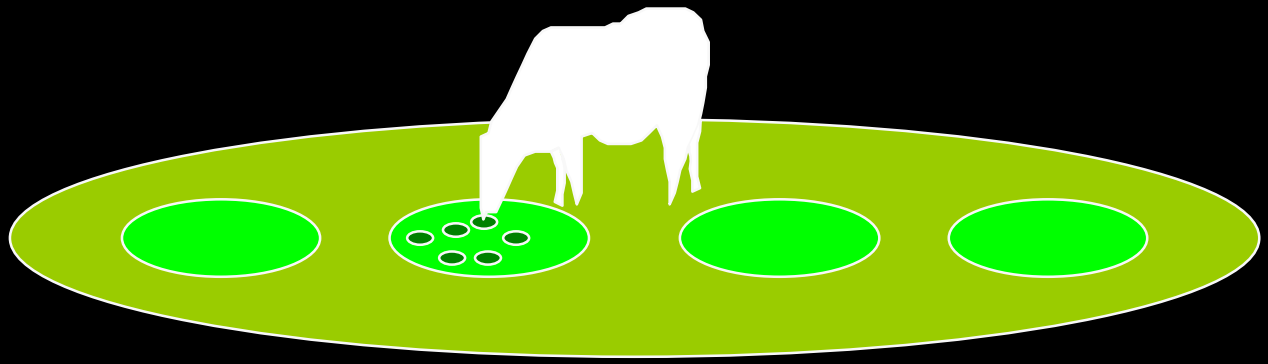


Predictability of resource distribution

Trade-offs

Habitat

Site



Patch Bite

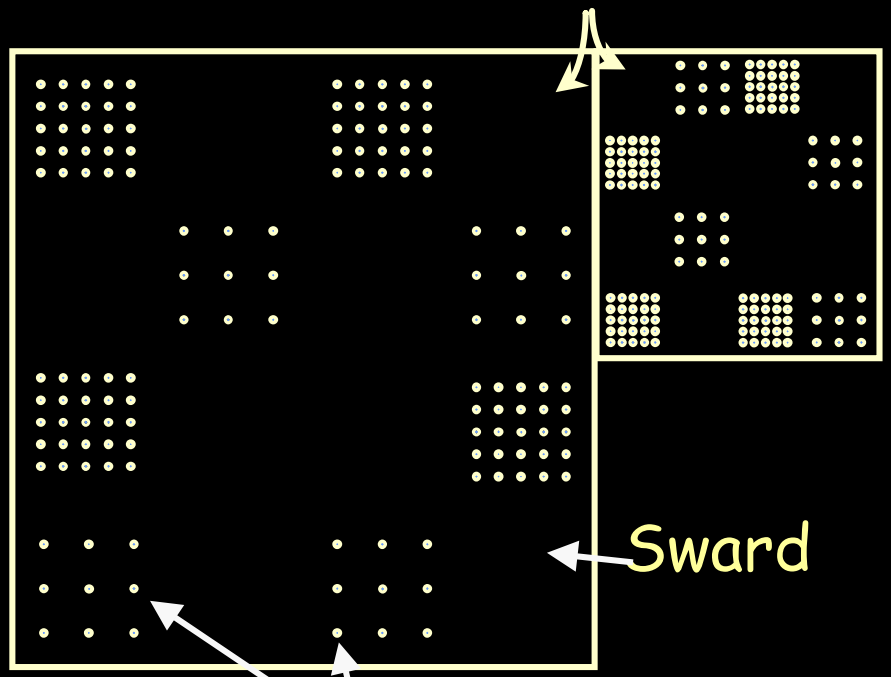
- Higher levels constrain behaviour at lower levels

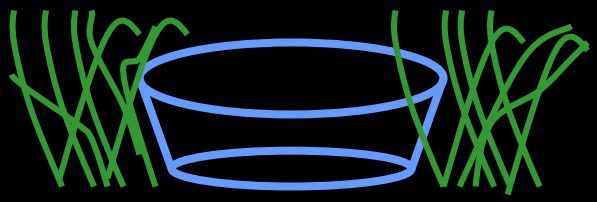
- Cost of a misplaced bite is less than that of a mistake at a higher level

=> Intake rate in herbivores is constrained by the efficient exploitation of intermediate levels (patch, site) in the hierarchy

1. **Understanding processes at the patch (and site) scales**
   - Cognitive abilities improve foraging efficiency and operate at different scales
   - Their use varies according to the complexity and predictability of the environment
   - Social peers modulate individual decisions at different scales
   - Trade-offs help to predict how herbivores distribute at the largest scales
2. **Assembling that understanding across scales**
   - Advantages and use of Agent-Based Models

Spatial memory is a key process



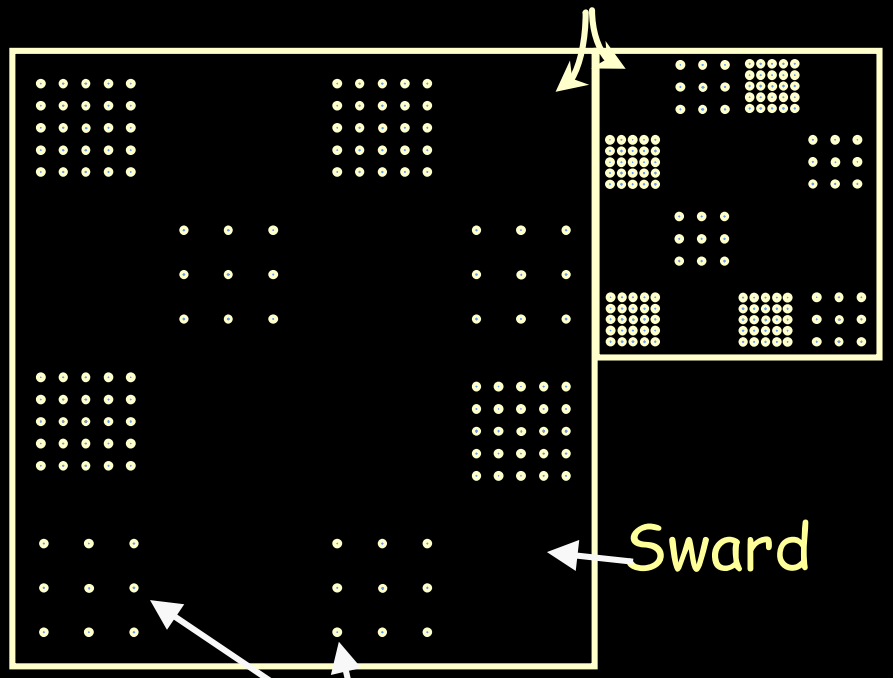


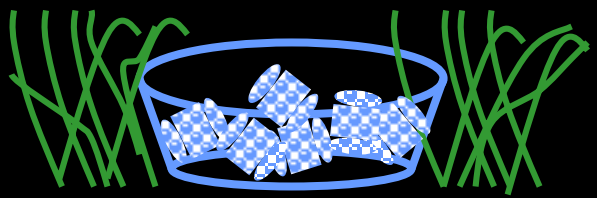
Two plot sizes

Constant sward height

Rich and poor patches

Spatial memory is a key process





Two plot sizes

Constant sward height

Rich and poor patches

Bowls filled every day

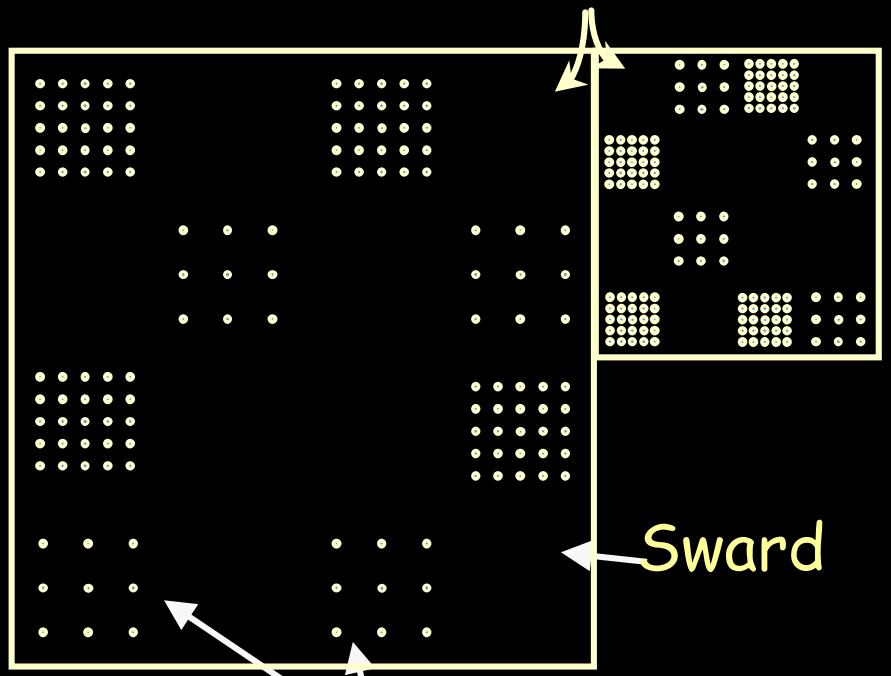
Same position over 12 d.

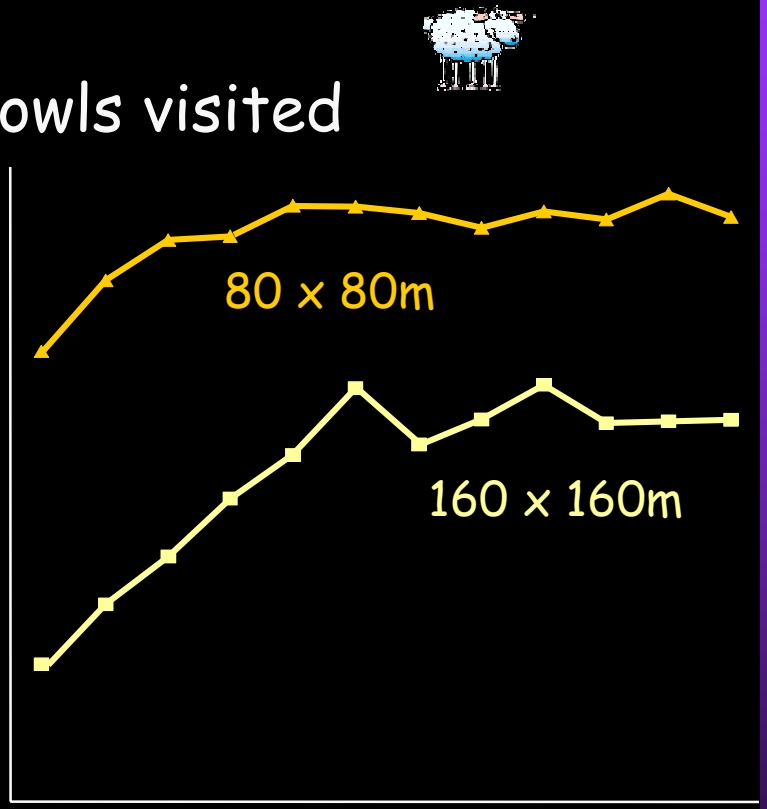
Groups of 3 sheep

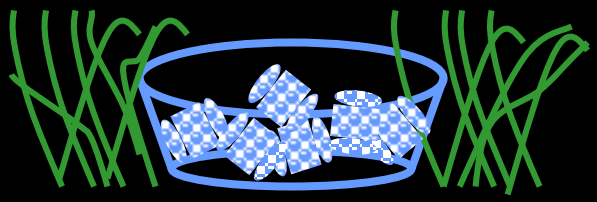
30' tests :

- activity
- visited bowls

Spatial memory is a key process

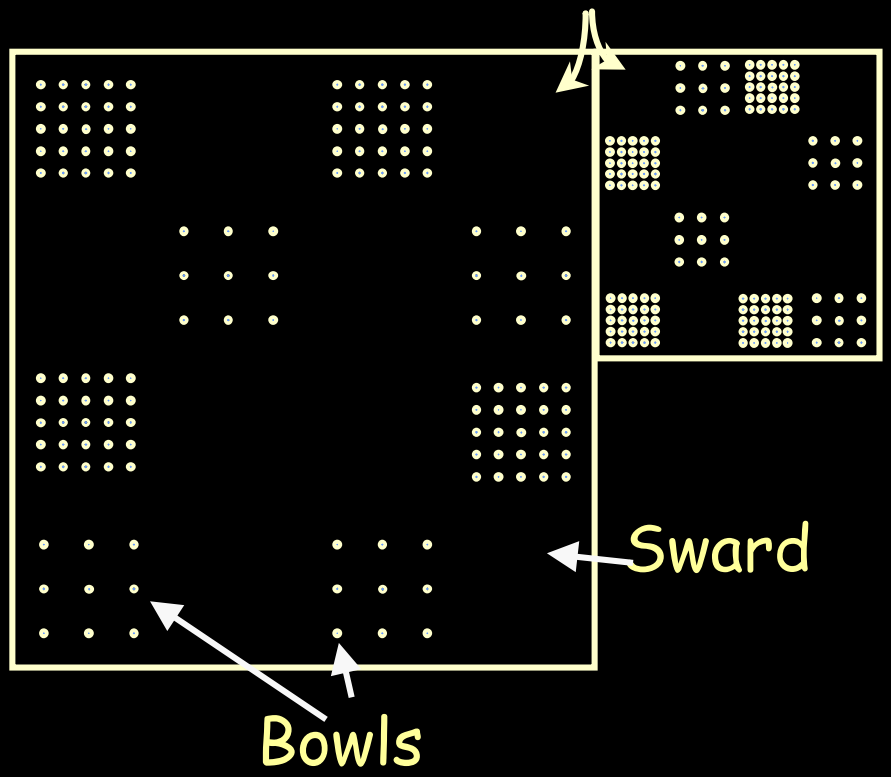


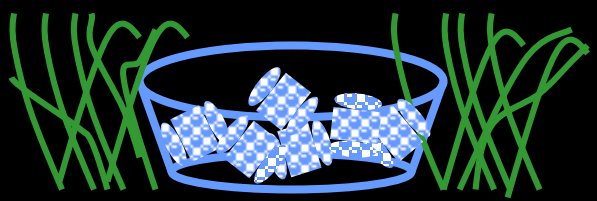


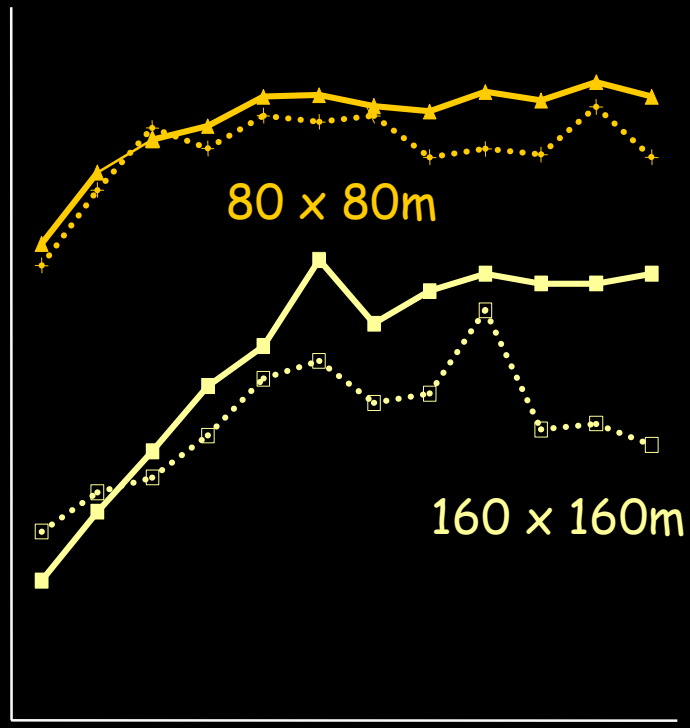


Dumont & Petit 1998

Rich patches are more intensively exploited

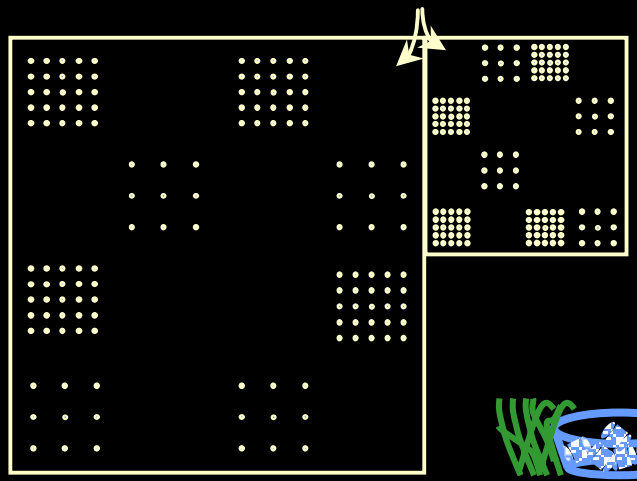




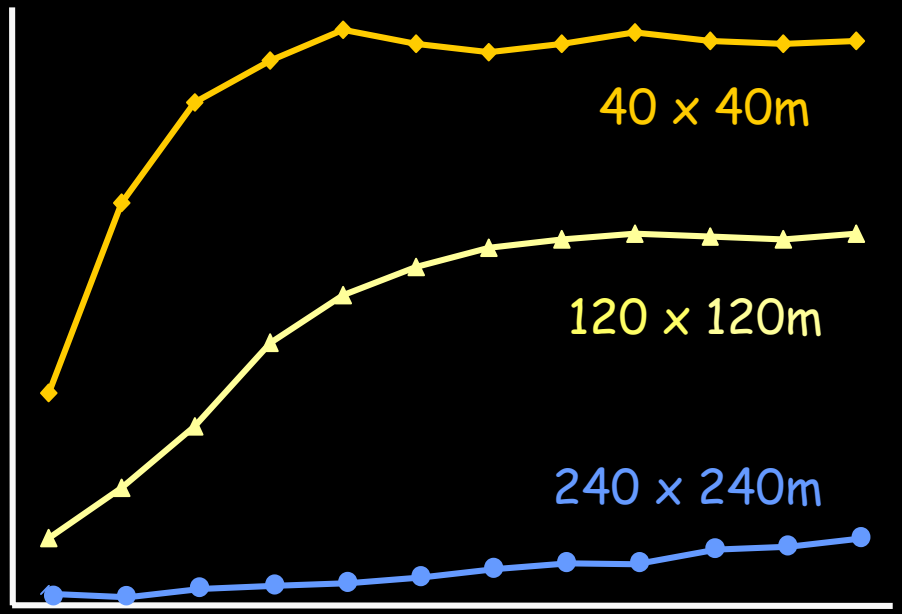


Dumont & Petit 1998

The adaptive value of spatial memory varies according to environment complexity



Bowls visited



Day

Multi-Agent model

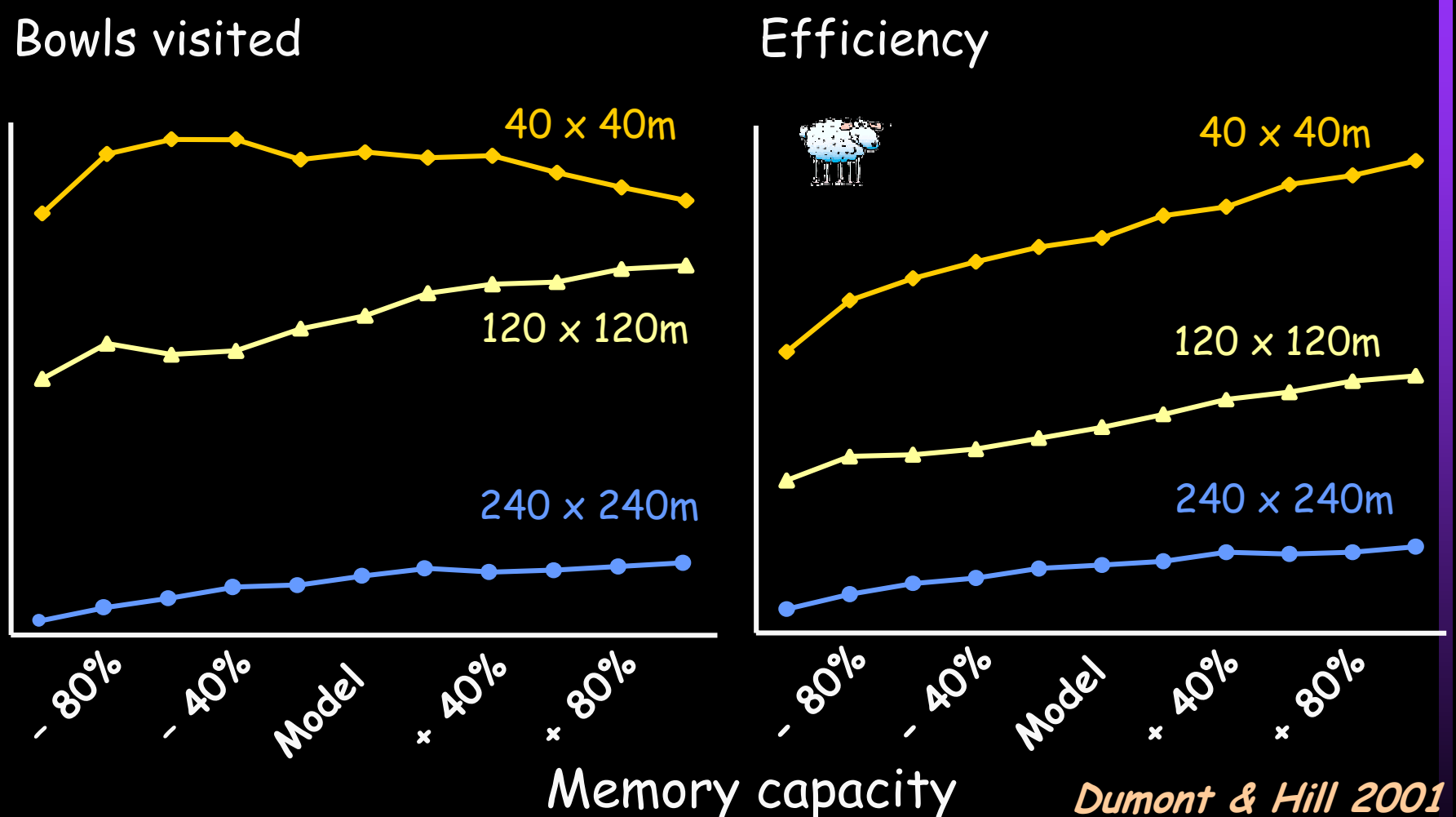
Parameter calibration

Extrapolation : plot size

memory capacity

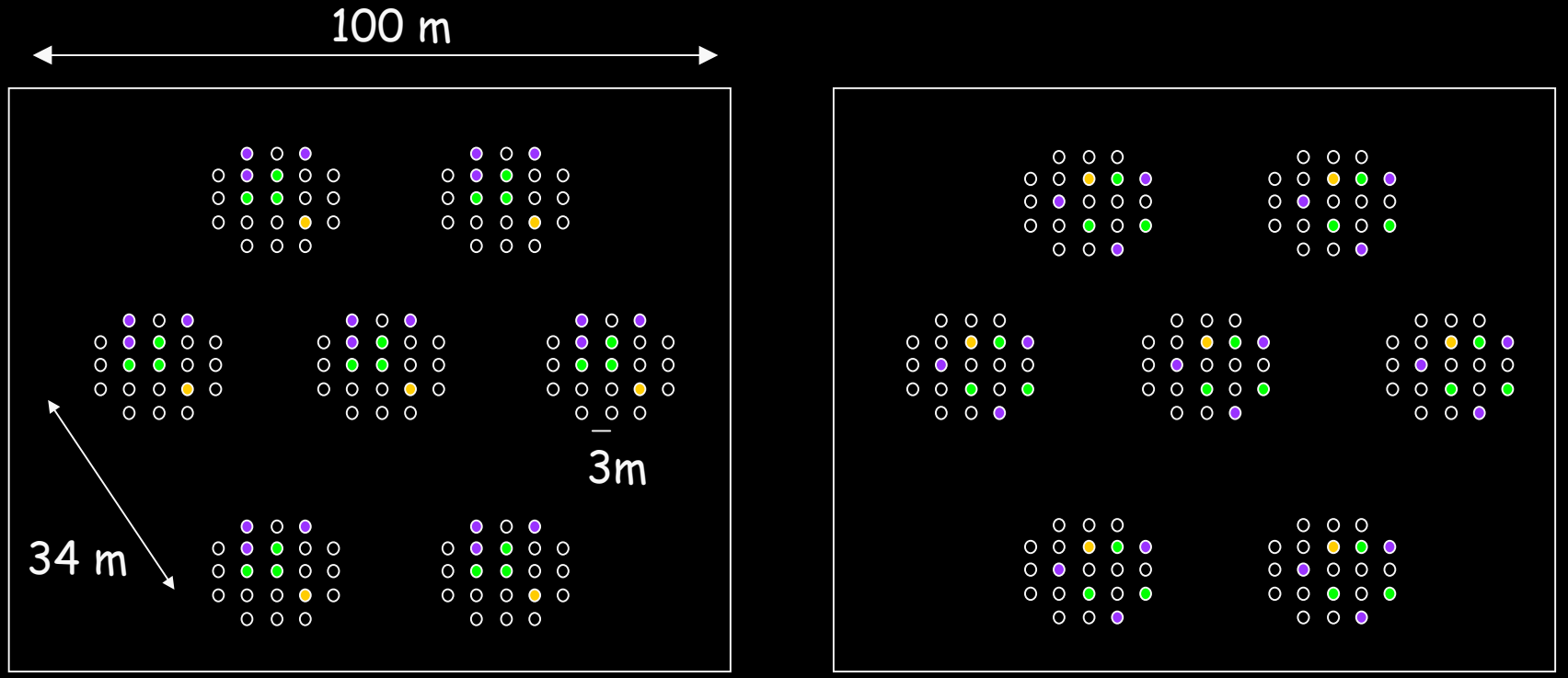
Dumont & Hill 2001

The adaptive value of spatial memory varies according to environment complexity



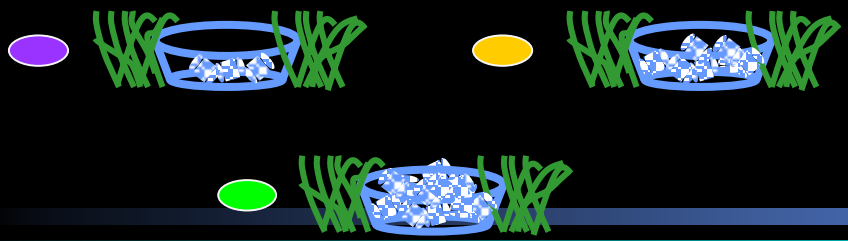
Dumont & Hill 2001

Patch exploitation when resource distribution becomes less predictable



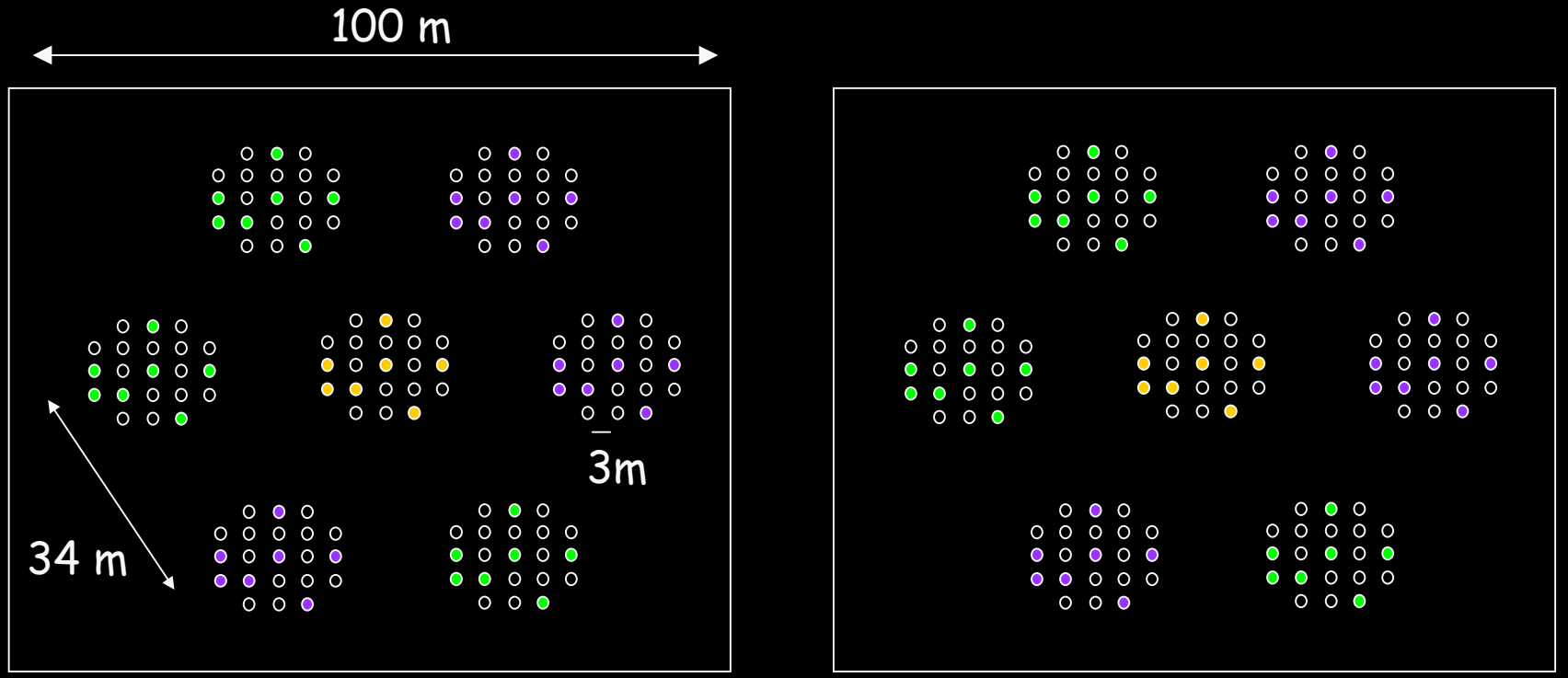
Day 1

Day 2 ...



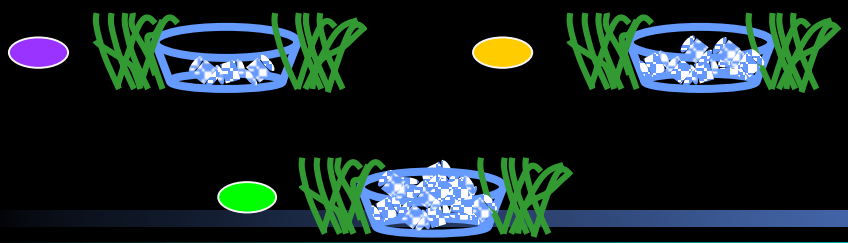
Variability within patch
No variability between patch

Patch exploitation when resource distribution becomes less predictable



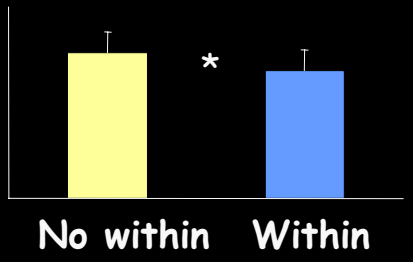
Day 1

Day 2 ...

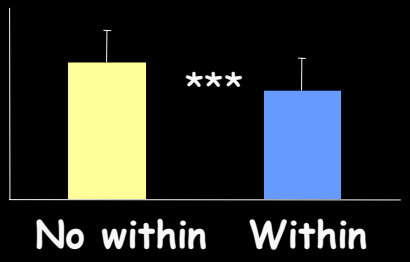


No variability within patch
Variability between patch

Efficiency (g pellets / min)



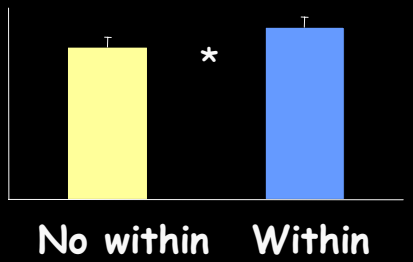
Full bowl visits / total visits



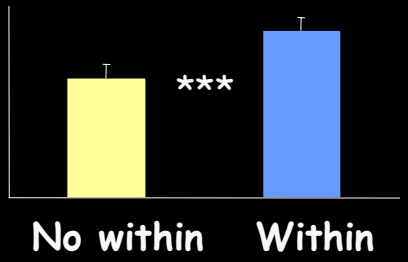
Use of spatial memory at a small scale (within patches)

Hewitson 2003

Patch visits



Giving-up threshold (s)



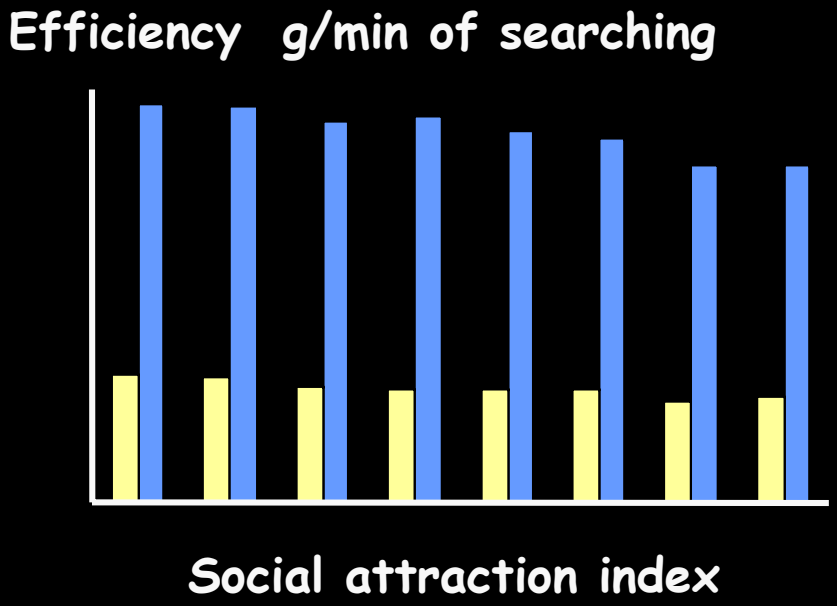
Sampling where rewarding positions varied within patch

Use of spatial memory and sampling varies according to environment complexity and predictability

Social peers influence searching efficiency

Leadership and social facilitation increase the searching efficiency of social foragers…

… but grouping tendencies can limit the learning of environments where patches deplete rapitly



80 x 80 m

160 x 160 m

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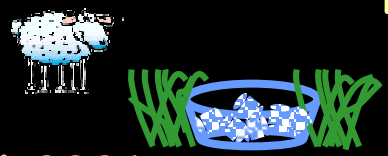


Missed opportunities

Competition on patches

Dumont & Hill 2001

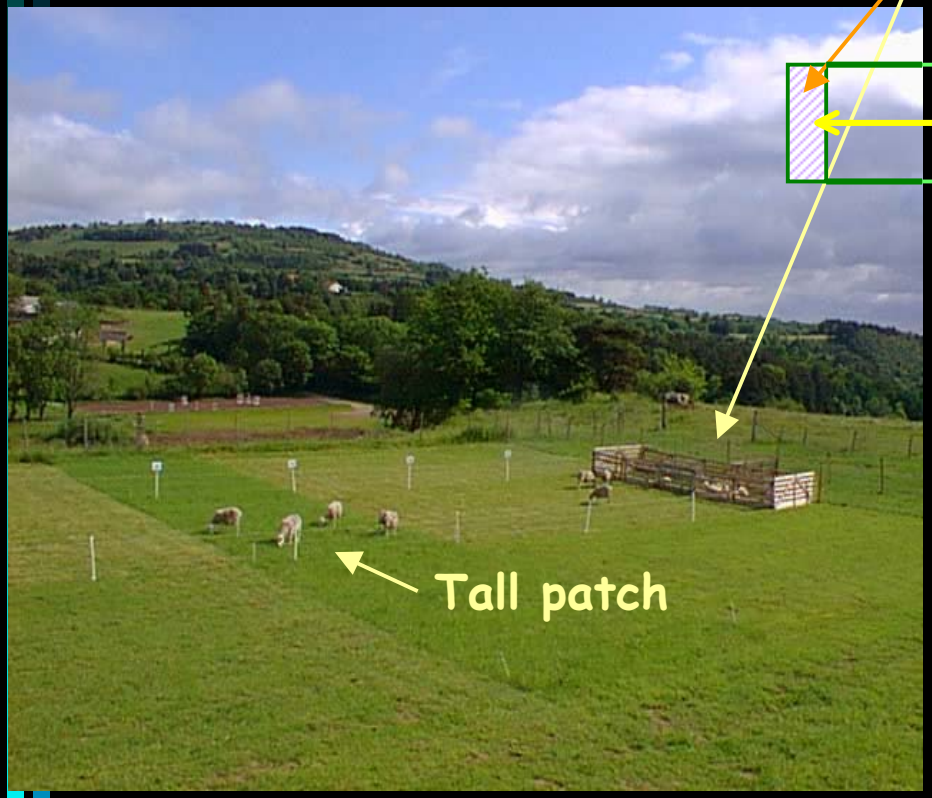
The strongest effect is on subordinate animals

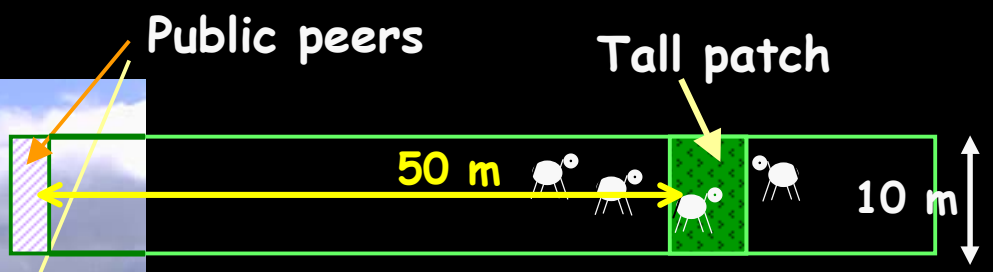
In grazing red deer, the subordinates have restricted access to preferred patches *(Appleby 1980)*

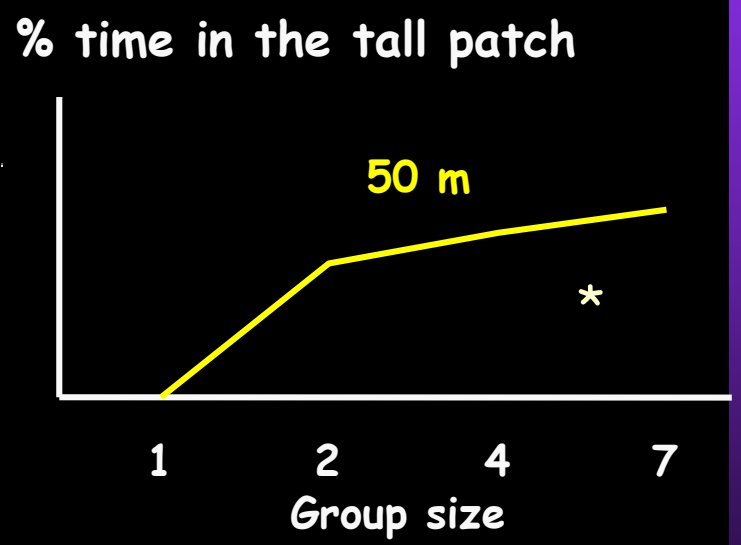
- are less synchronised with the dominants and their growth rate is more affected *(Blanc & Thériez 1998)*
- have a lower biting rate when near the dominants *(Thouless 1990)*

In a indoor test with sheep, the subordinates moved more to the next patch when the relative difference in the dominance hierarchy was low *(Hewitson 2003)*

Trade-off between food and social peers



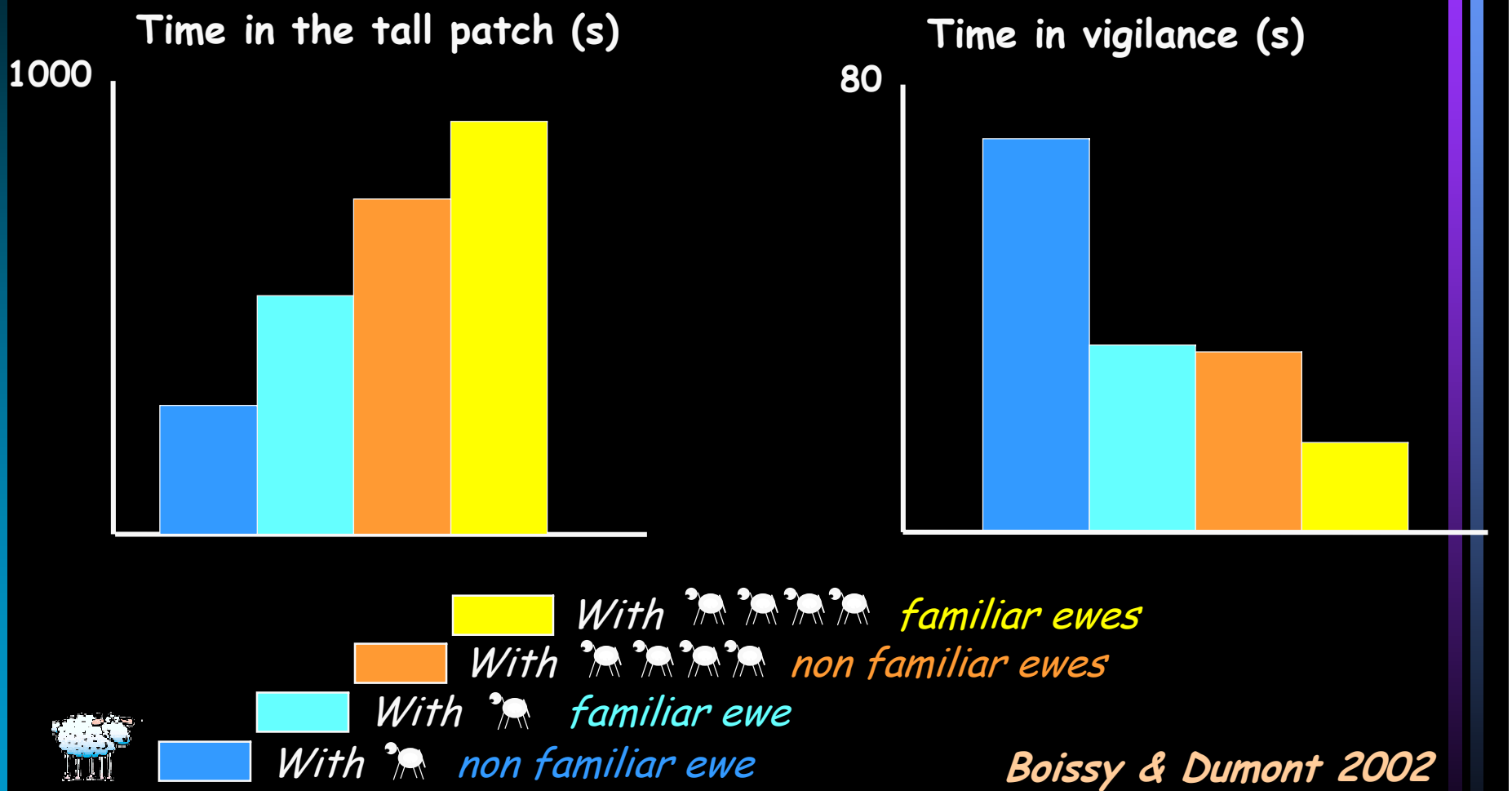




Dumont & Boissy 2000

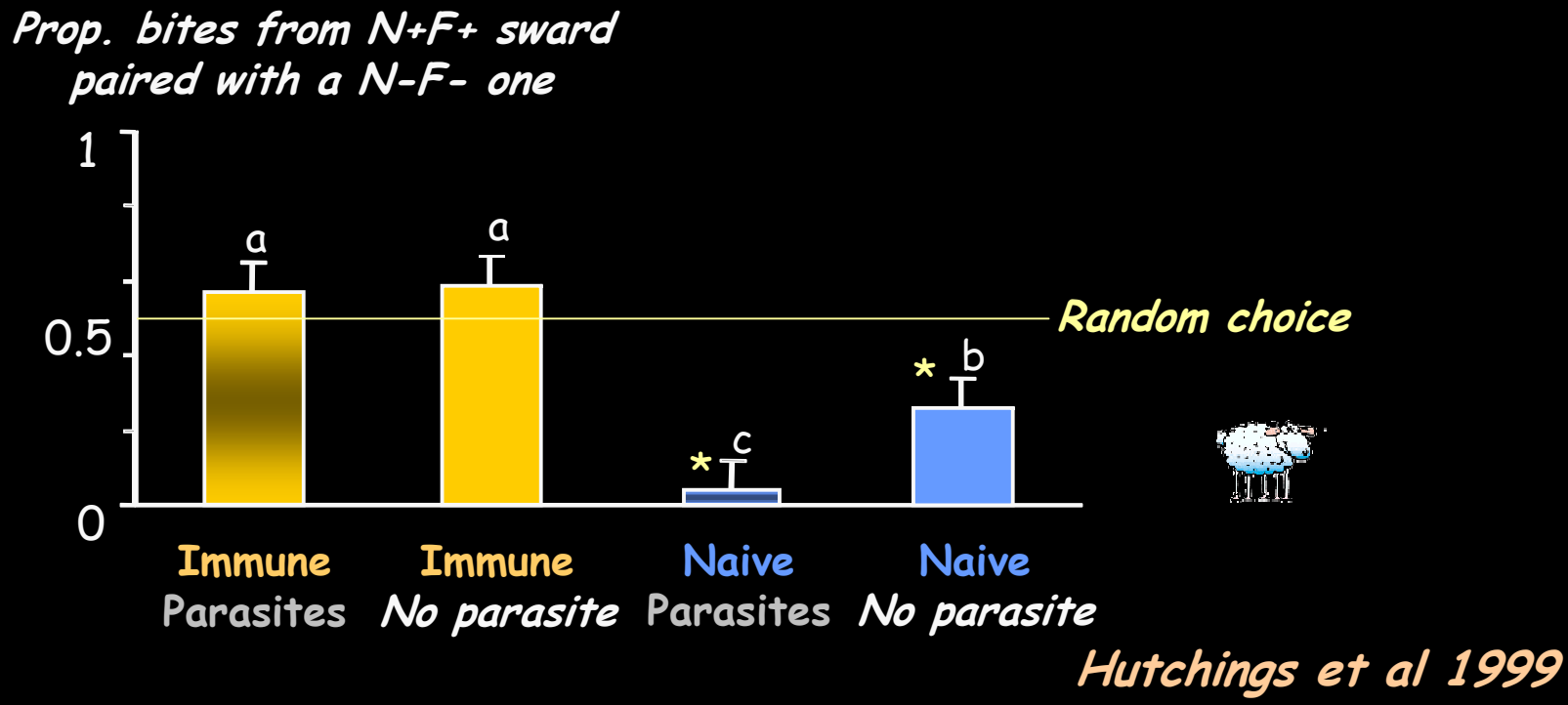
Conflict between the motivation to maintain social contact and to express a food preference

The strength of social bonds modulates the way herbivores respond to this conflict



Trade-off between food and the risk of parasitism

Animal state affects whether animals take the trade-off or not



Hutchings et al 1999

Results from short duration tests are in agreement with observations made in a free-ranging population on St Kilda where parasitism has a major effect on sheep survival

Trade-offs between food and the risk of predation or with the need for shelter determine herbivore distribution at the landscape scale

Deer subject to predation by mountain lions spend less time foraging, have higher giving-up densities of food, and have higher vigilance behaviour when occupying the edge of a forest than when in open areas and forest interiors

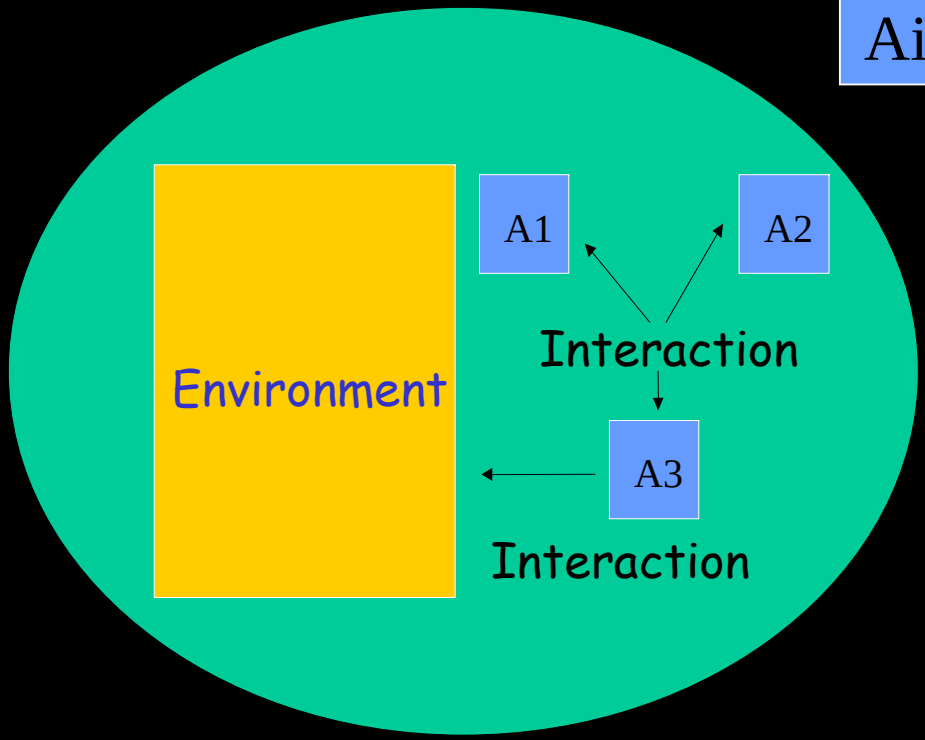
Altendorf et al 2001

- Cognitive abilities improve foraging efficiency and operate at different scales
- Their use varies according to the complexity and predictability of the environment
- Social peers modulate individual decisions at different scales
- Trade-offs help to predict how herbivores distribute at the largest scales

Only combining experimentation with models will satisfy our desire to integrate and organize findings into a meaningful picture of herbivore foraging

Advances in ethology and behavioural ecology are predominantly individual based

ABMs to understand the role of individual foraging decisions and of their interactions in the creation and maintenance of heterogeneity at multiple scales



Ai

Is active

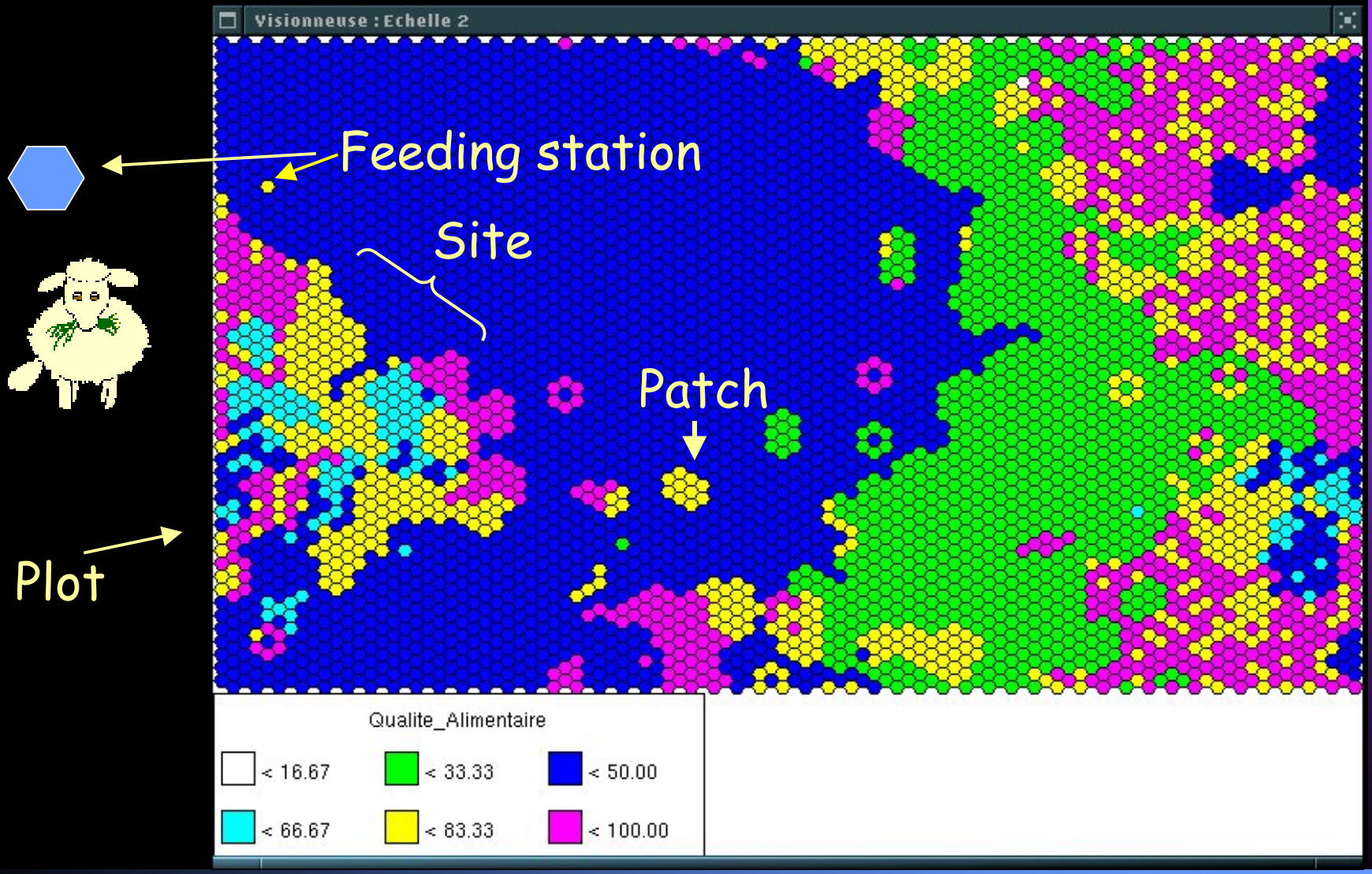
Has its own operational autonomy

Has its own characteristics

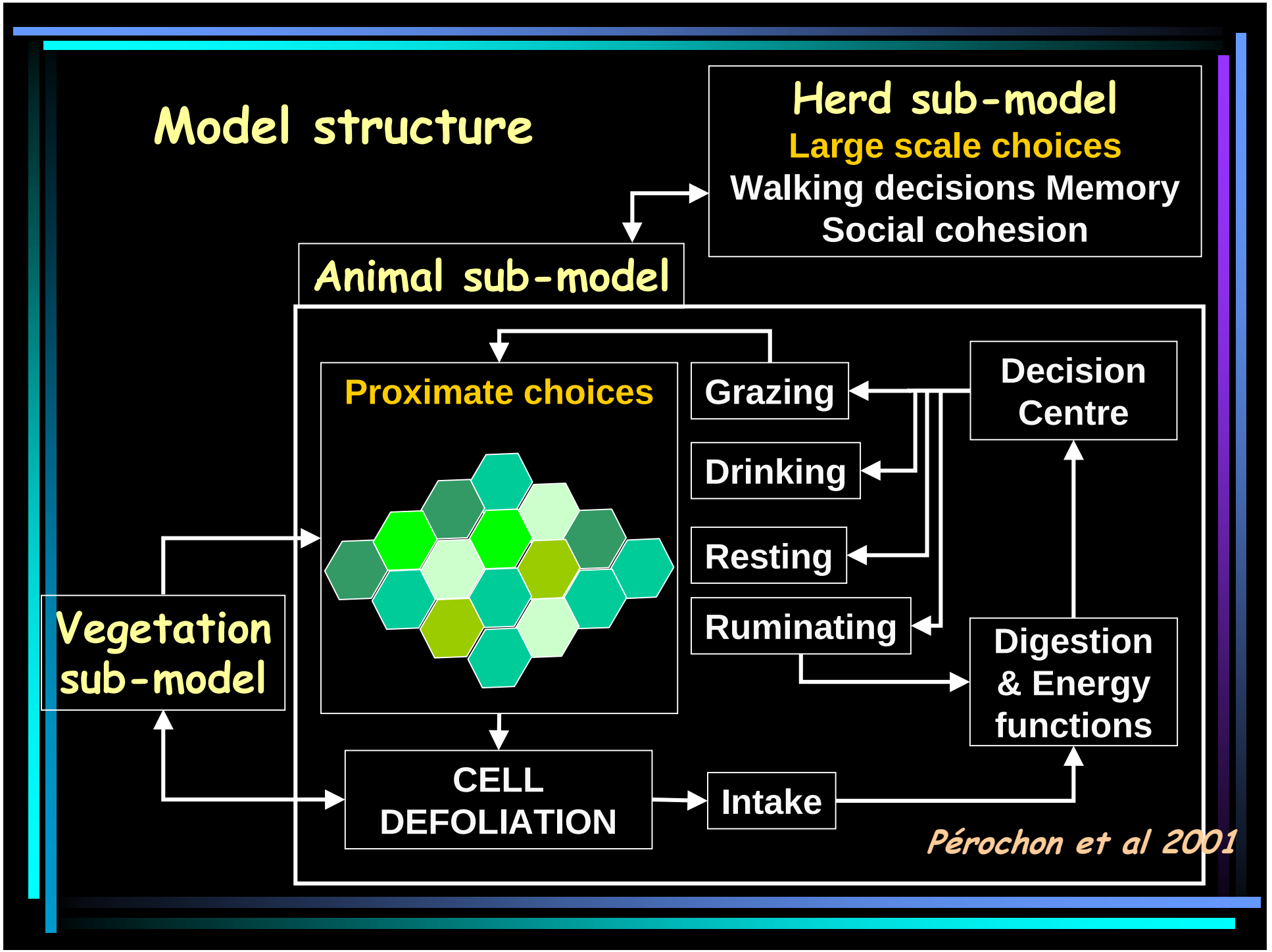
Interacts with other agents and with the environment

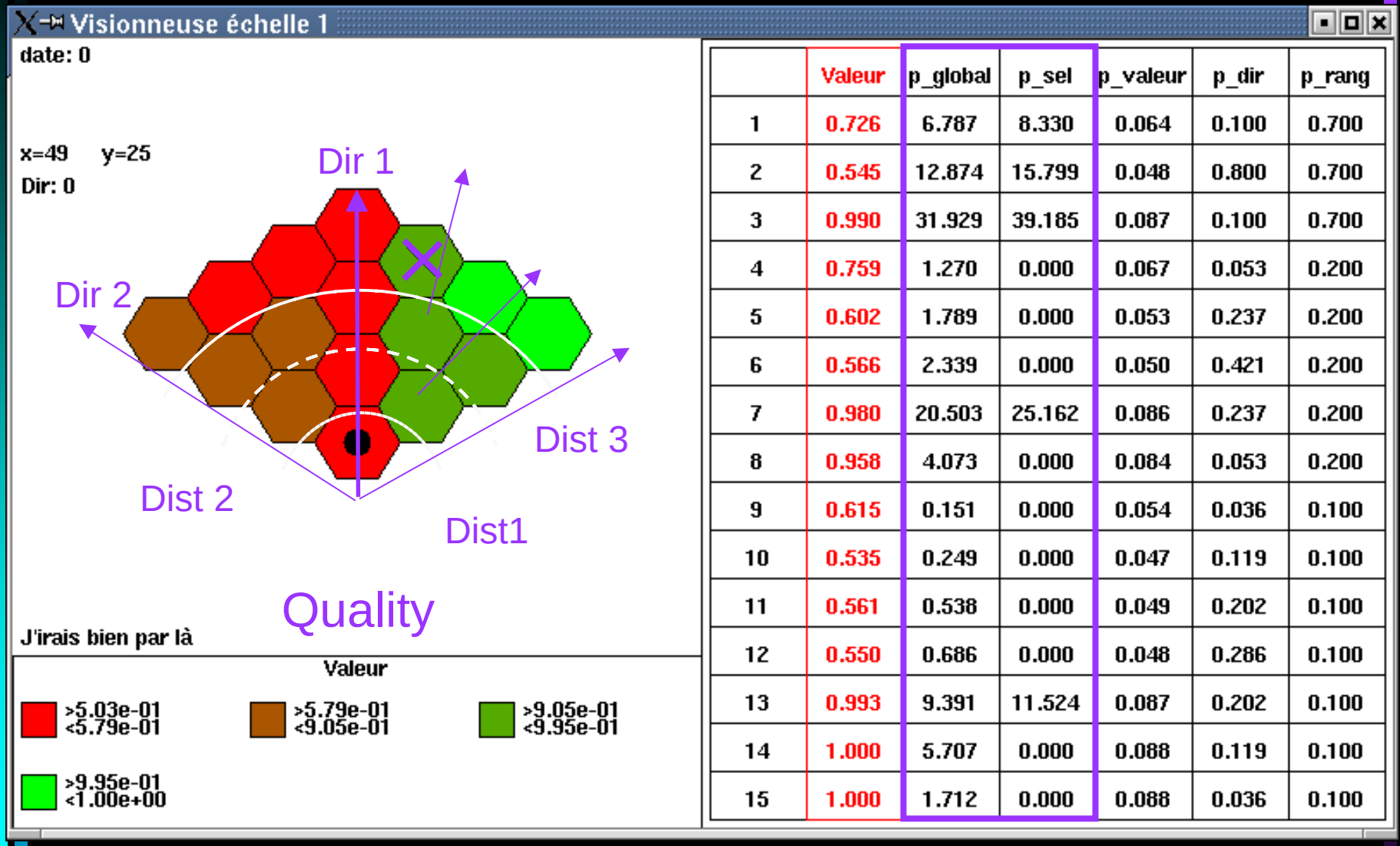
Performs its tasks locally but influence the global behaviour of the system

A hierarchy of scales within the environment



Model structure



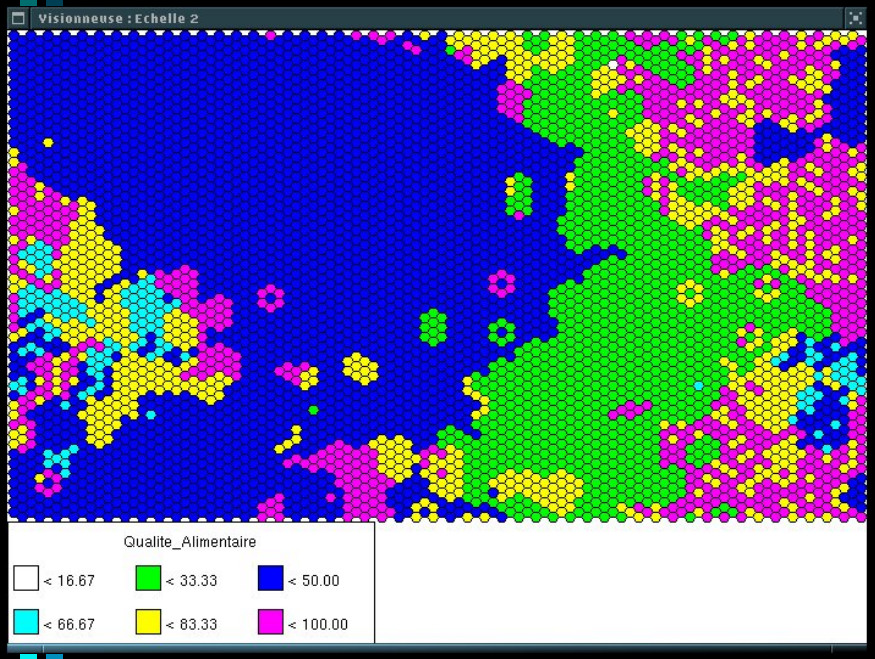


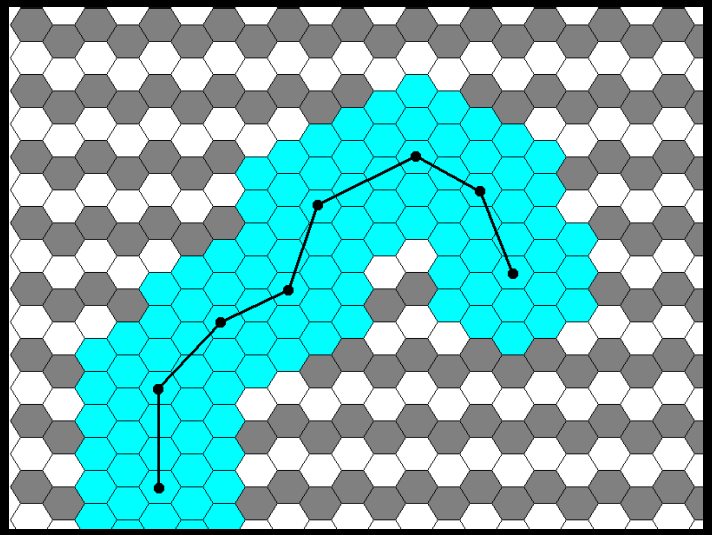
	Valeur	p_global	p_sel	p_valeur	p_dir	p_rang
1	0.726	6.787	8.330	0.064	0.100	0.700
2	0.545	12.874	15.799	0.048	0.800	0.700
3	0.990	31.929	39.185	0.087	0.100	0.700
4	0.759	1.270	0.000	0.067	0.053	0.200
5	0.602	1.789	0.000	0.053	0.237	0.200
6	0.566	2.339	0.000	0.050	0.421	0.200
7	0.980	20.503	25.162	0.086	0.237	0.200
8	0.958	4.073	0.000	0.084	0.053	0.200
9	0.615	0.151	0.000	0.054	0.036	0.100
10	0.535	0.249	0.000	0.047	0.119	0.100
11	0.561	0.538	0.000	0.049	0.202	0.100
12	0.550	0.686	0.000	0.048	0.286	0.100
13	0.993	9.391	11.524	0.087	0.202	0.100
14	1.000	5.707	0.000	0.088	0.119	0.100
15	1.000	1.712	0.000	0.088	0.036	0.100

Choice probability = Quality ^{a} * Dist ^{b} * Dir ^{c}

Baumont et al 2002

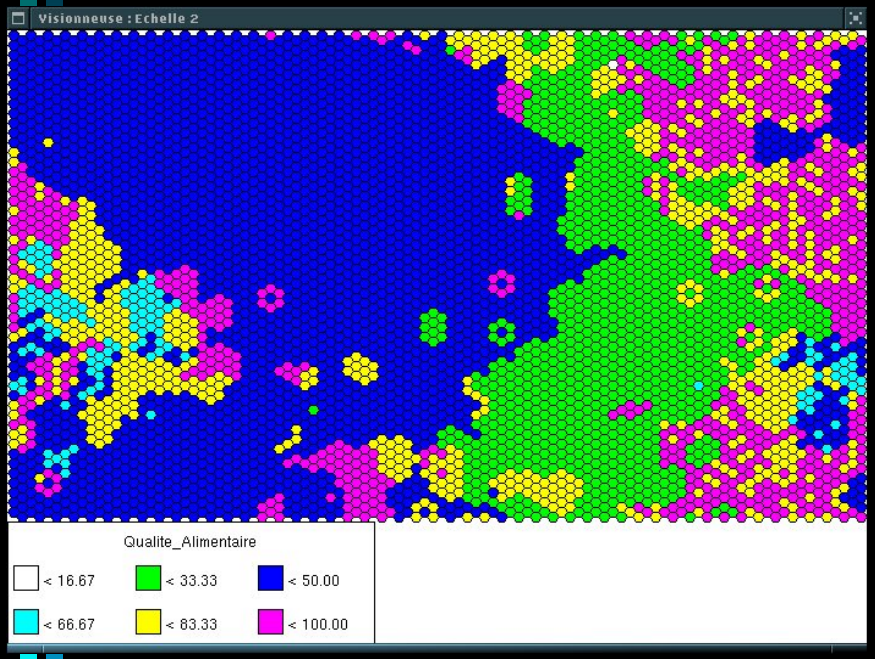
Use of spatial memory

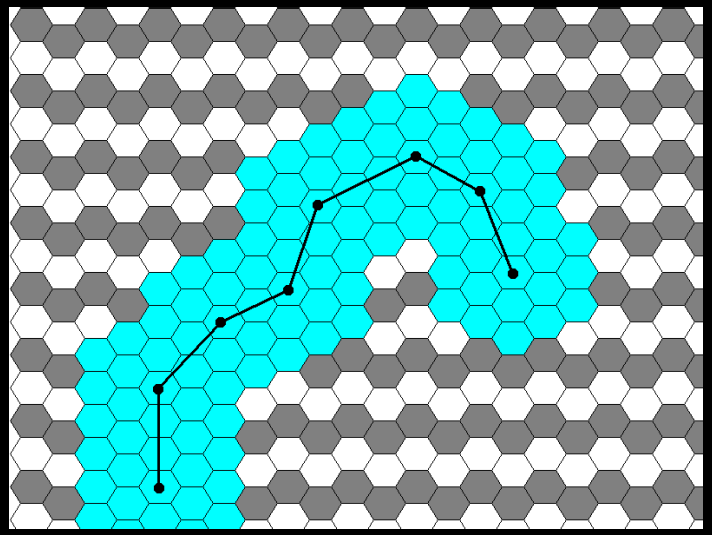




- Memory has a maximum size
- Spatial uncertainity
- Memory decay *(forget less frequently visited sites)*
- Memory *vs.* exploration

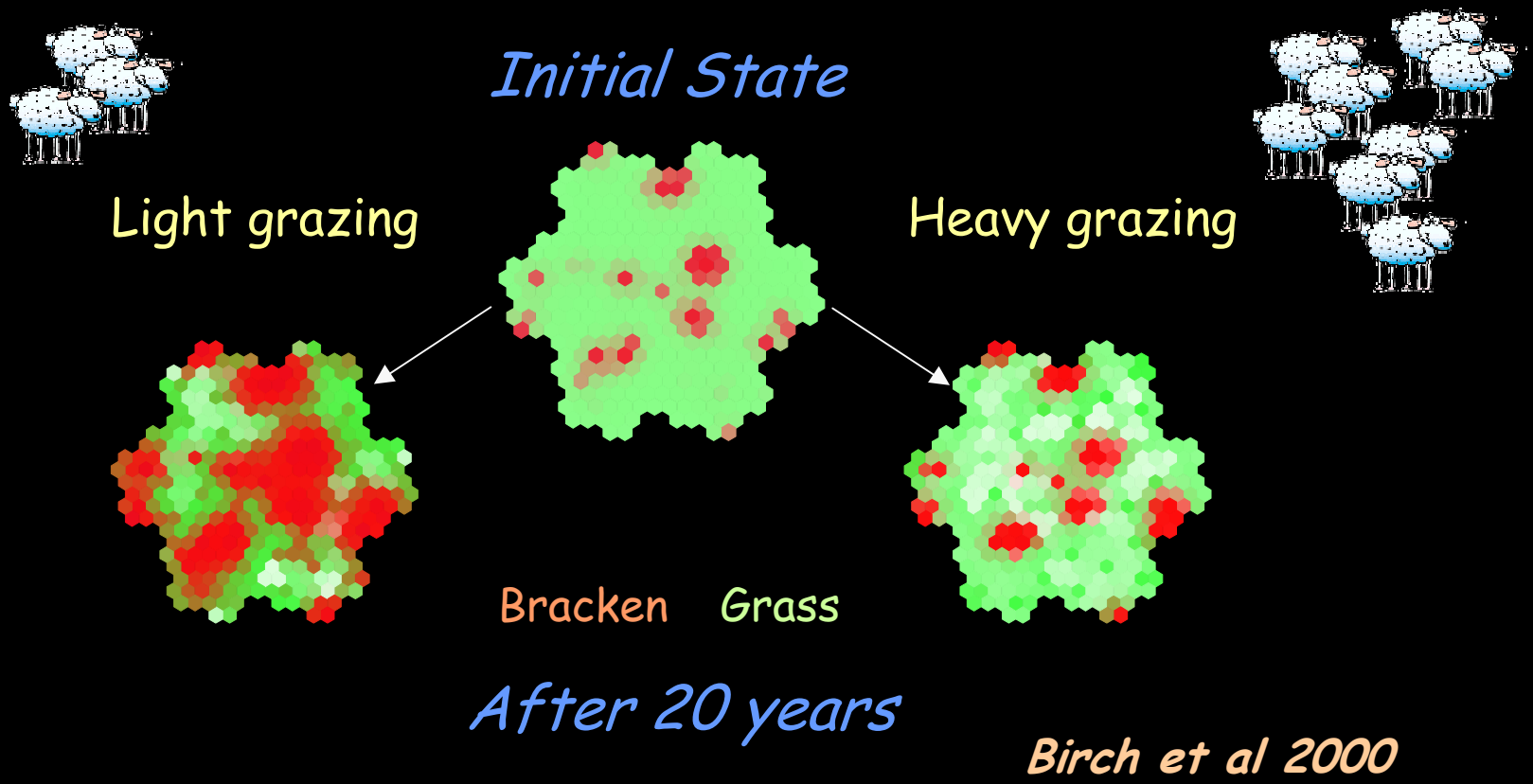
Learning of vegetation distribution

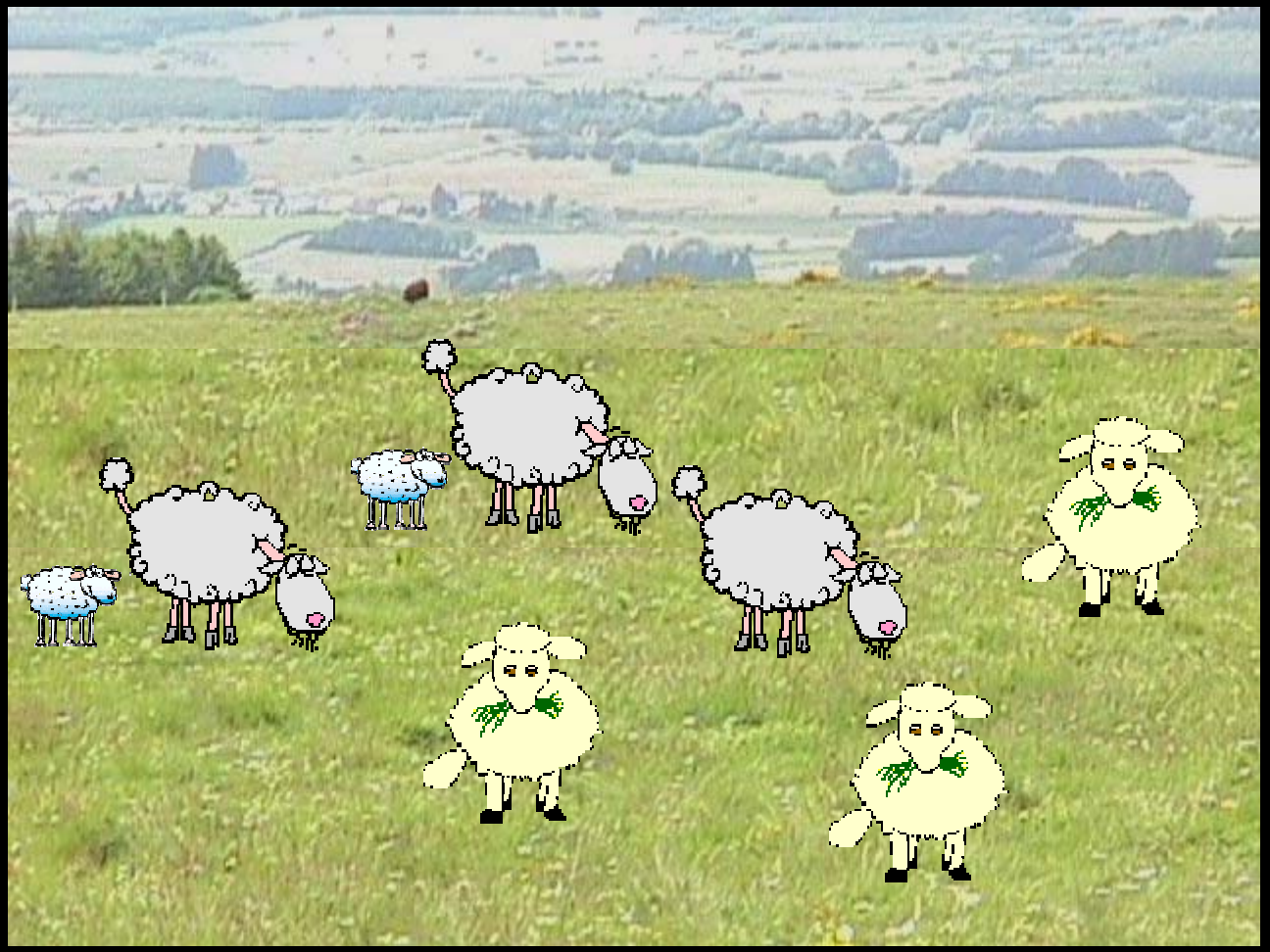




Dumont et al 2002

ABMs allow to integrate and organize findings at different scales, but can also be used as a Decision Support Tool





Thanks for your attention