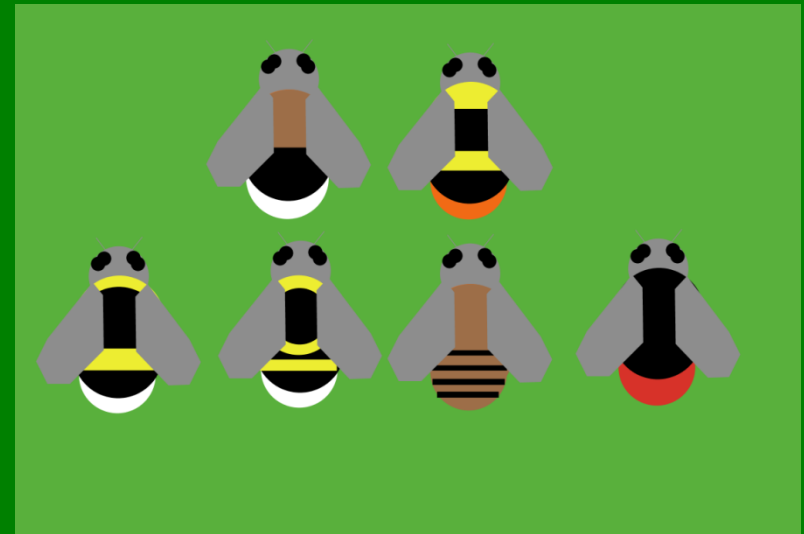
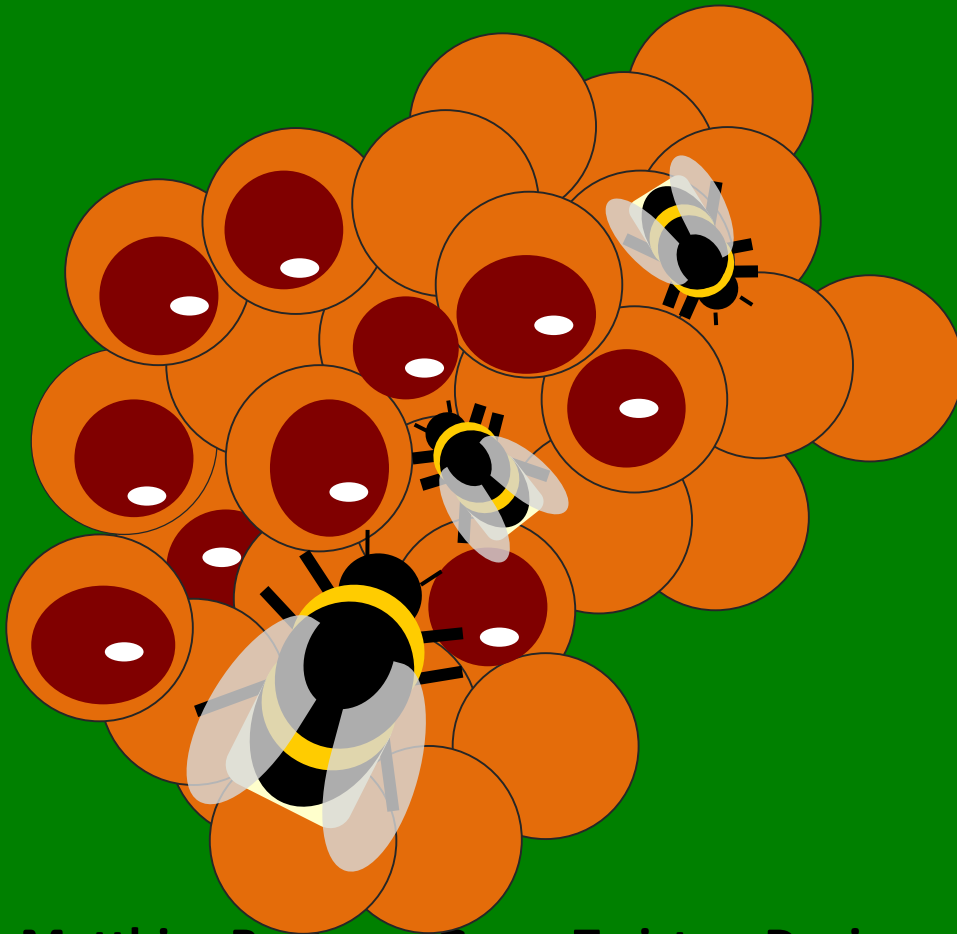


Understanding BEE-STEWARD

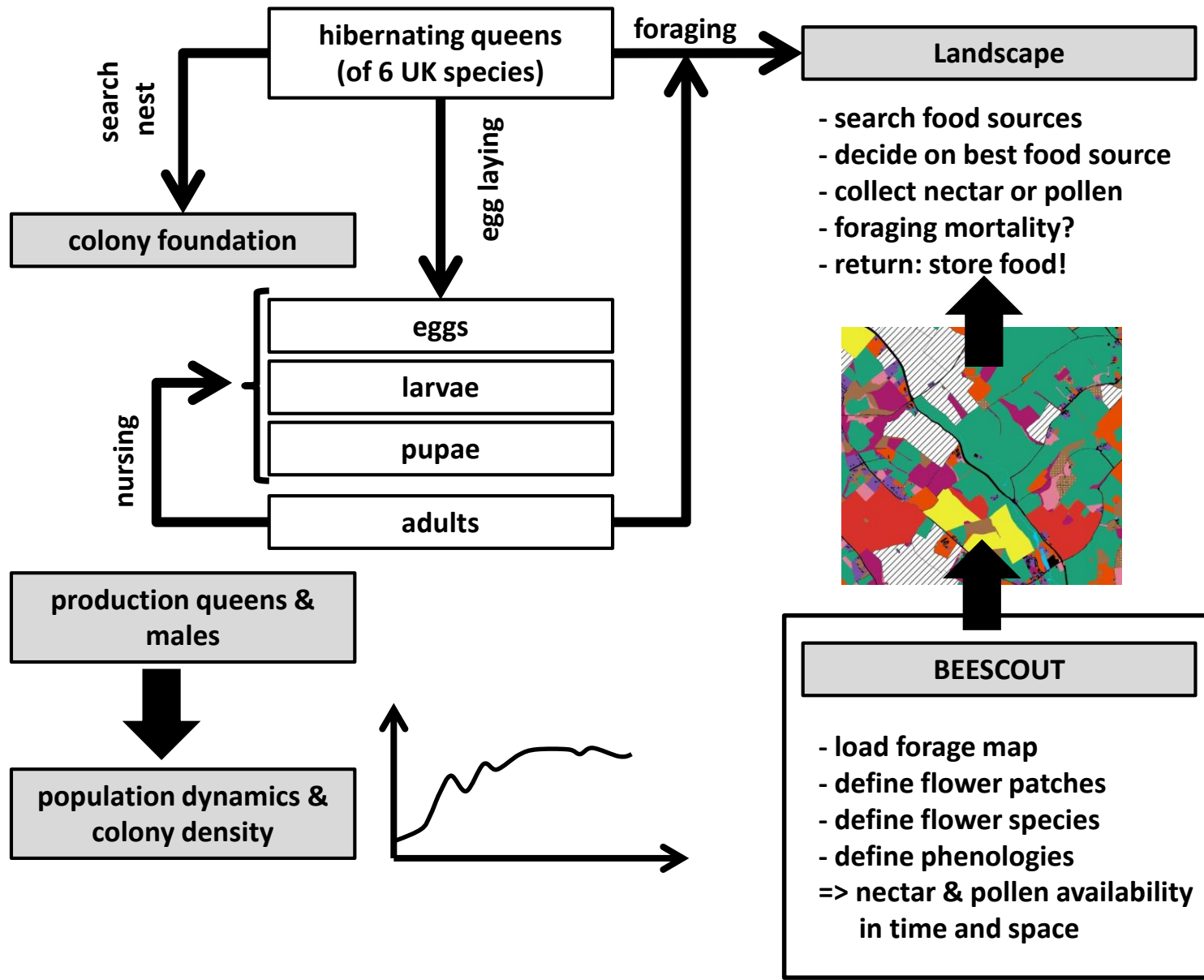
A Visual Introduction



Matthias Becher • Grace Twiston-Davies • Juliet Osborne

Twiston-Davies, Becher & Osborne. [DATE]. BEE-STEWARD: a research and decision support software for effective land management to promote bumblebee populations. [JOURNAL,(),-].

Overview: Simulated Processes



Implemented in NetLogo 5.3.1

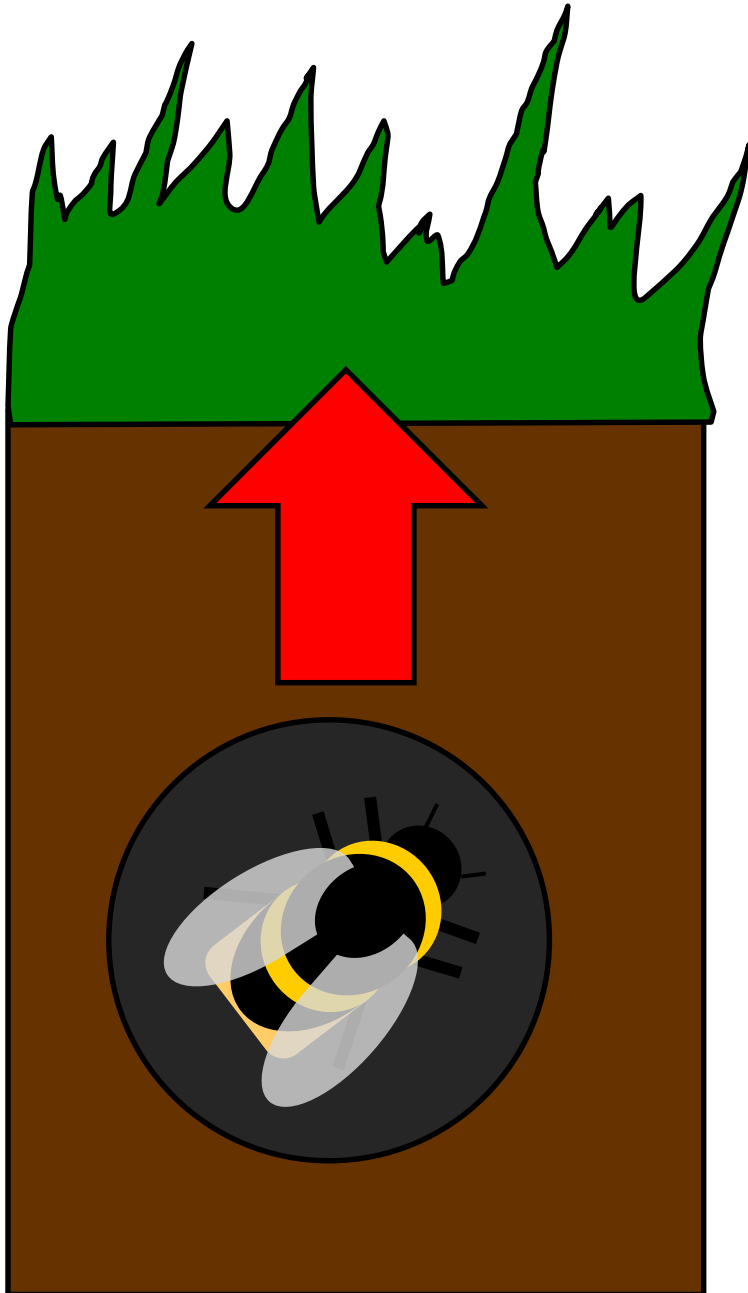
Wilensky, U. (1999) <http://ccl.northwestern.edu/netlogo/>

Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Simulated Processes

DETAILS

Queens emerging from hibernation



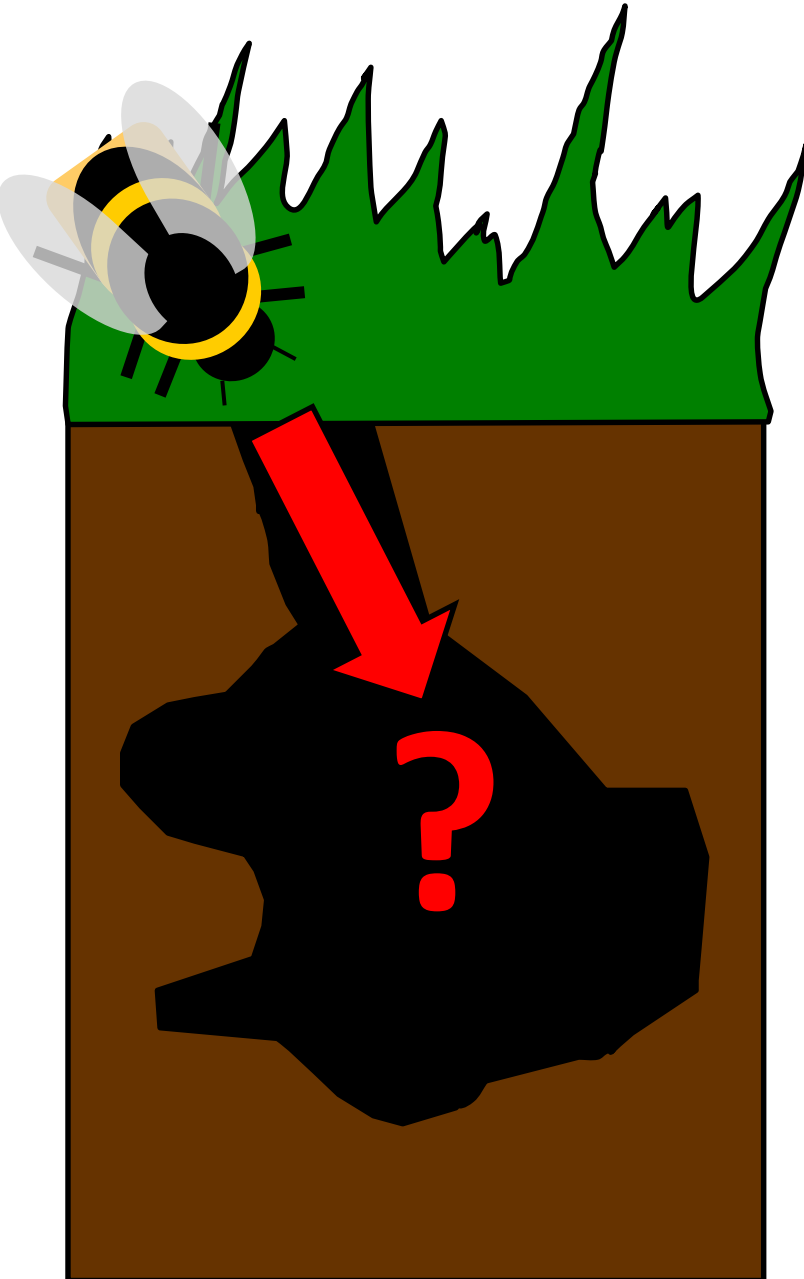
WHEN?

=> normally distributed around average date

SURVIVAL?

=> based on relative weight of the queen

Queens nesting sites



defined nesting habitats for species
unlimited nest density

daily probability to find a nest
daily risk to die if unsuccessful

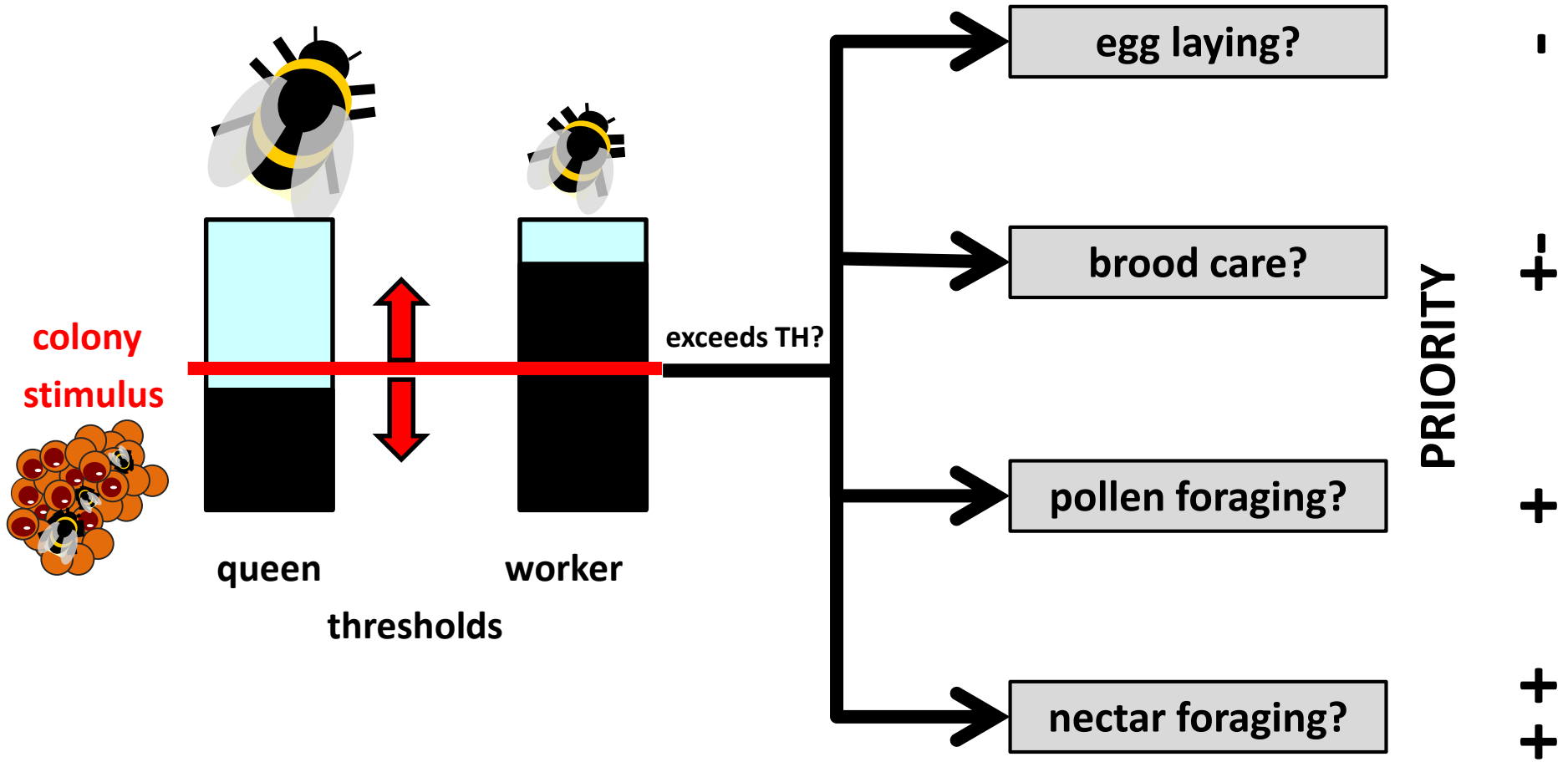
Founding nests



- collect nectar and pollen
- finally lay first batch of eggs

Decision making?

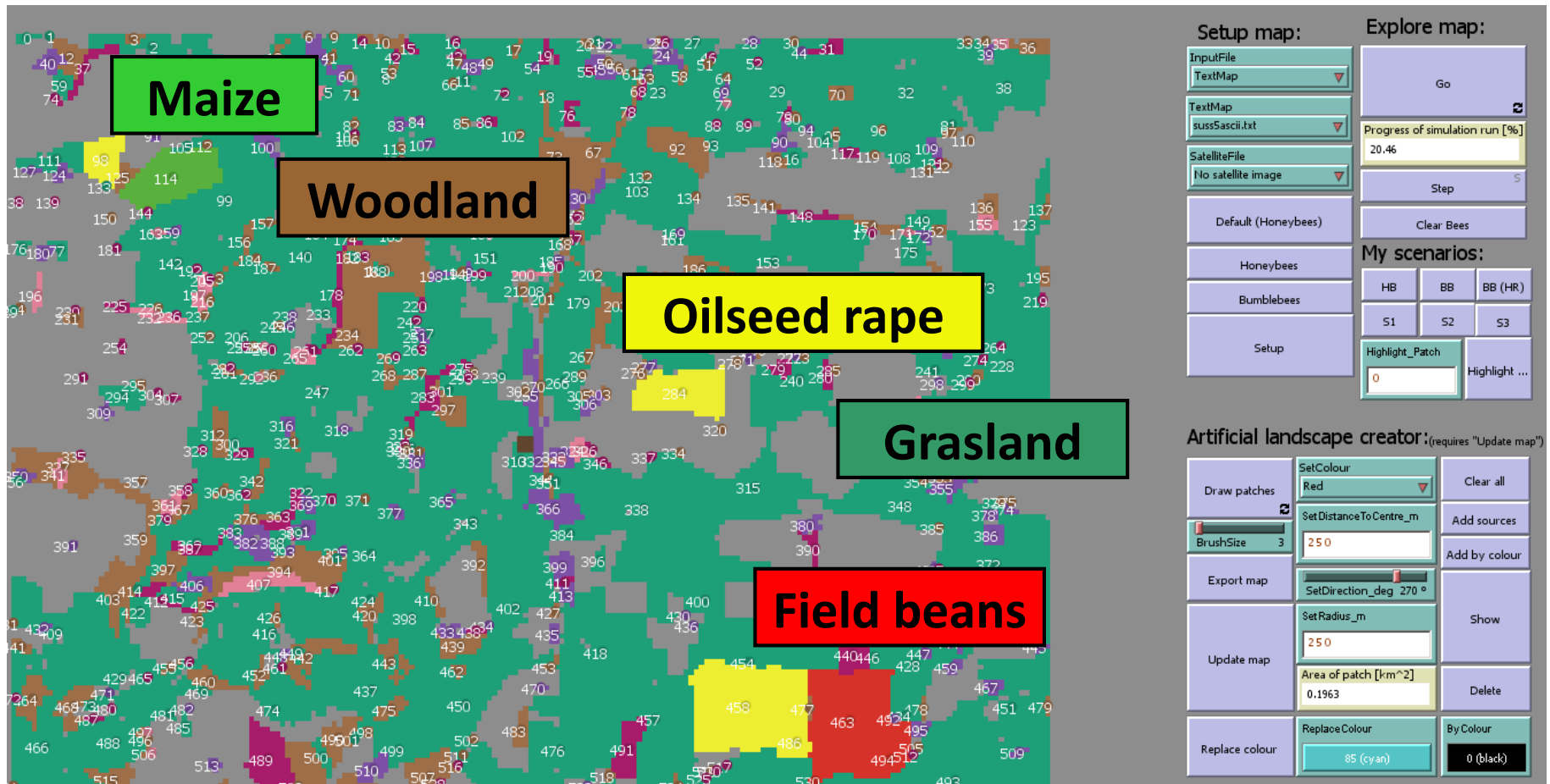
Activities - decision making



FORAGING:

How to define landscape?

The landscape module of BEESCOUT



Import land cover map (image)

Identify fields/patches

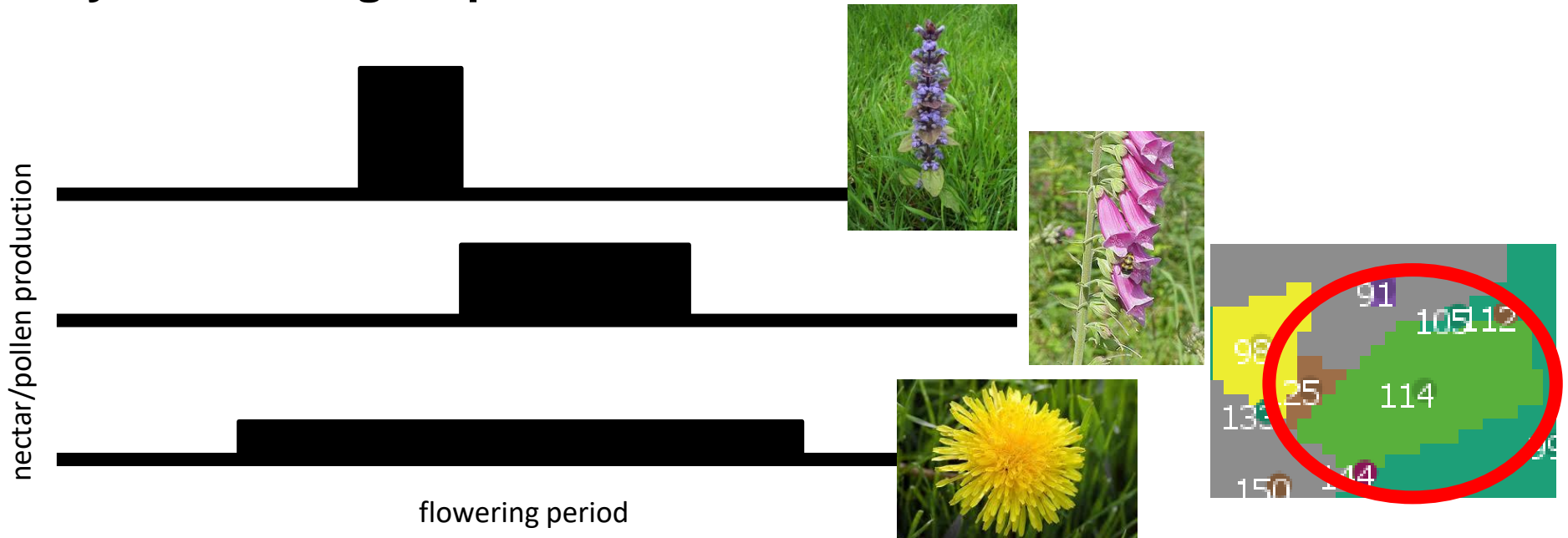
Define resources

Ecological Modelling (2016) 340: 126–133

food sources: nectar & pollen flow

semi-natural habitat:

"layers" of single species food sources



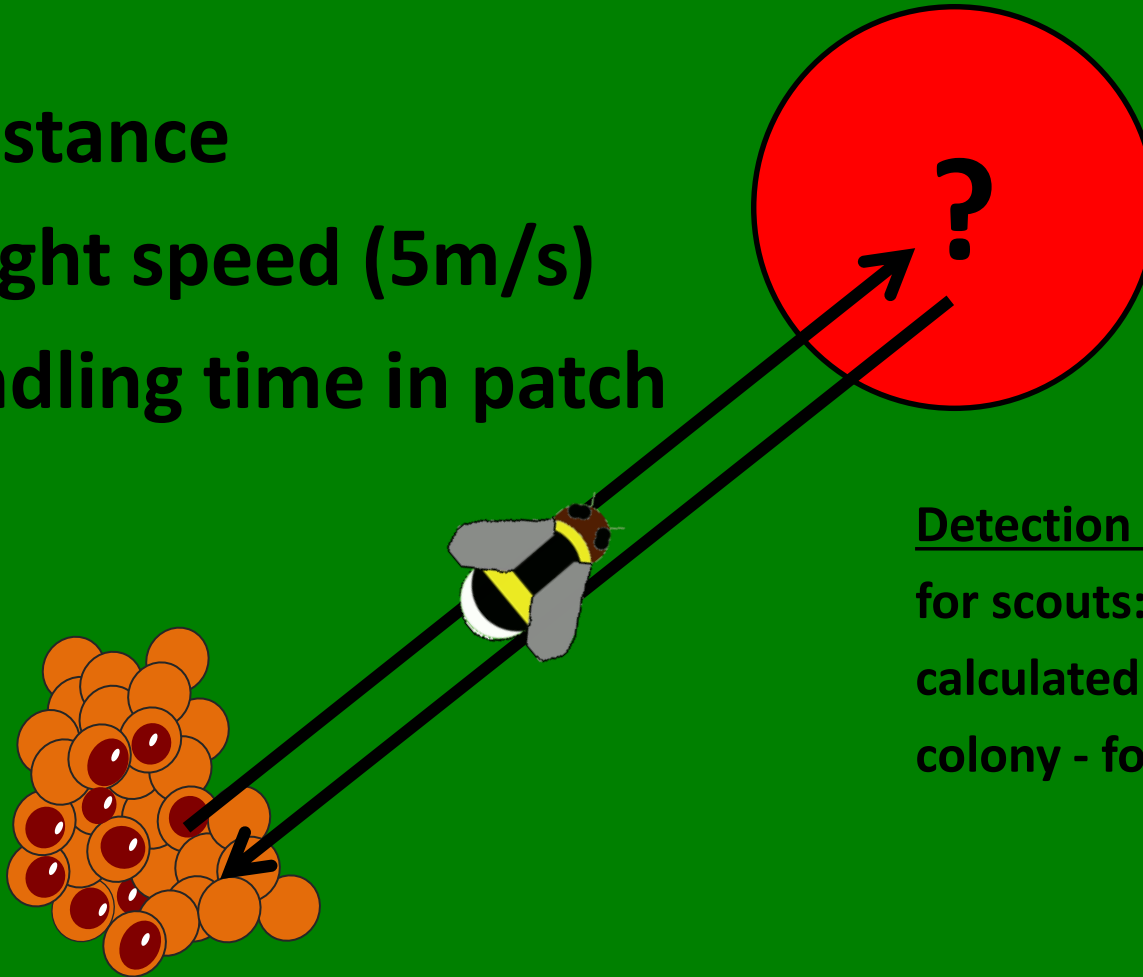
=> nectar & pollen production/m² during flowering period

FORAGING:

Trip duration & decision making

Trip duration

2 x distance
/ flight speed (5m/s)
+ handling time in patch



Detection probability
for scouts:
calculated from distance
colony - food patch

Foraging: Handling time

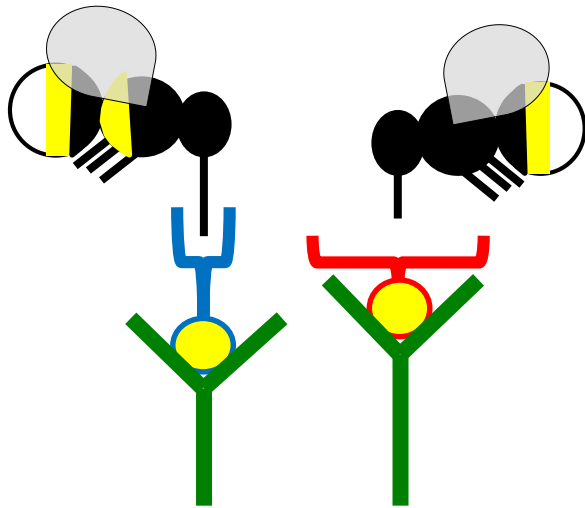
Handling time: based on model by Harder

Harder 1983

Oecologia 57:274-280

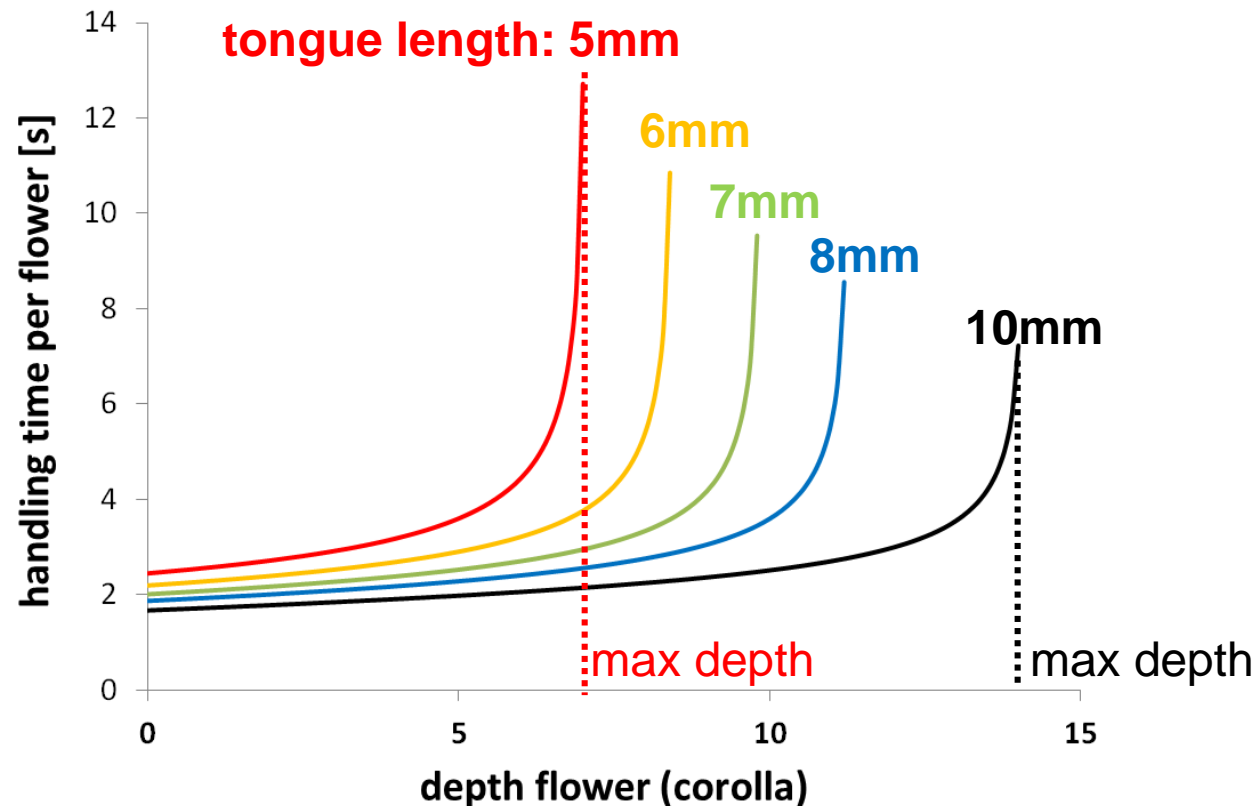
long

short tongued bees

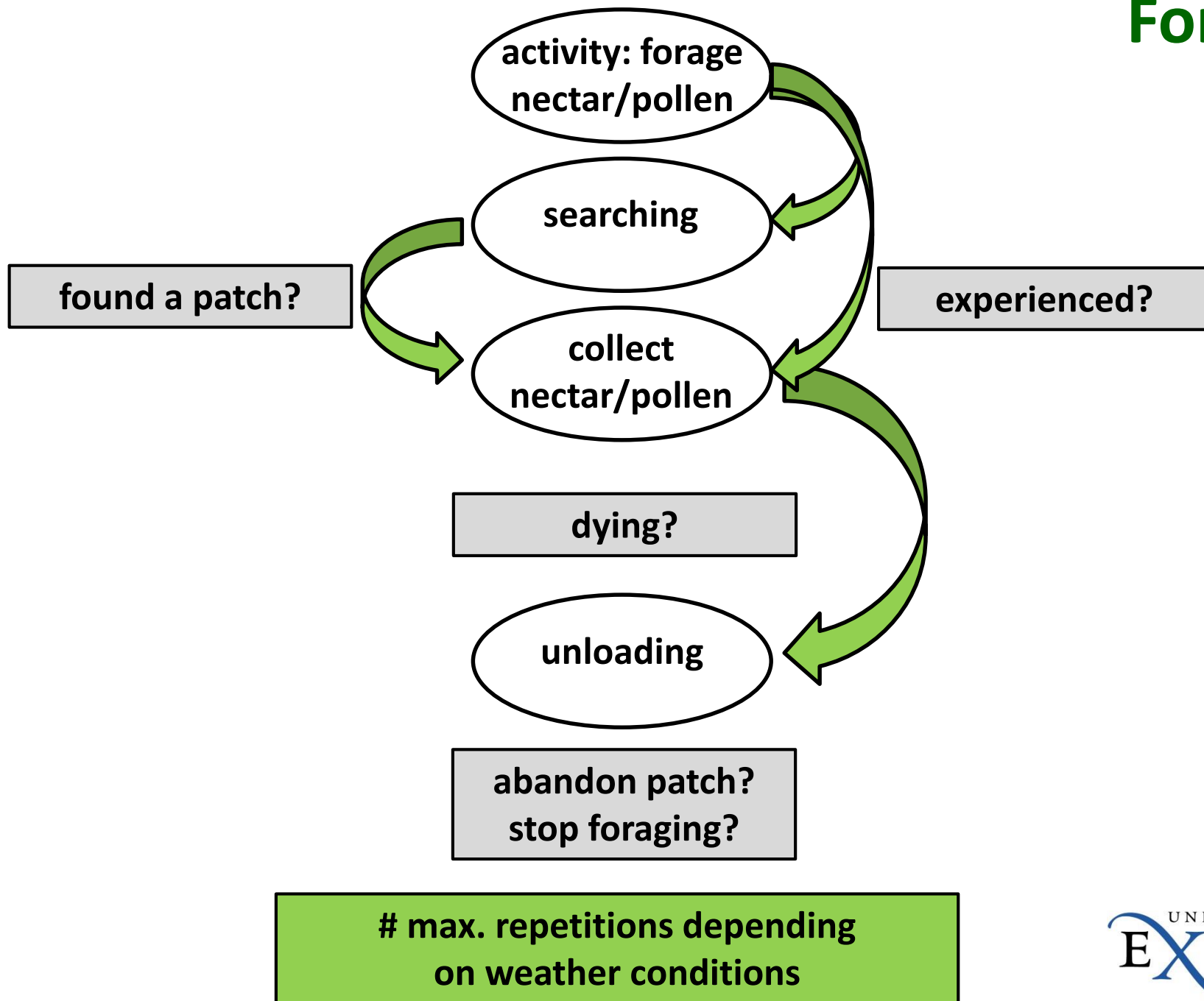


flower depth

**also: flower volume
depletion of patch**



Foraging



Brood care



Nectar & pollen stores present

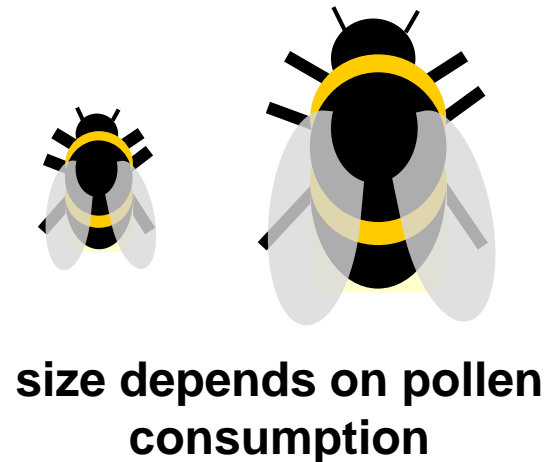
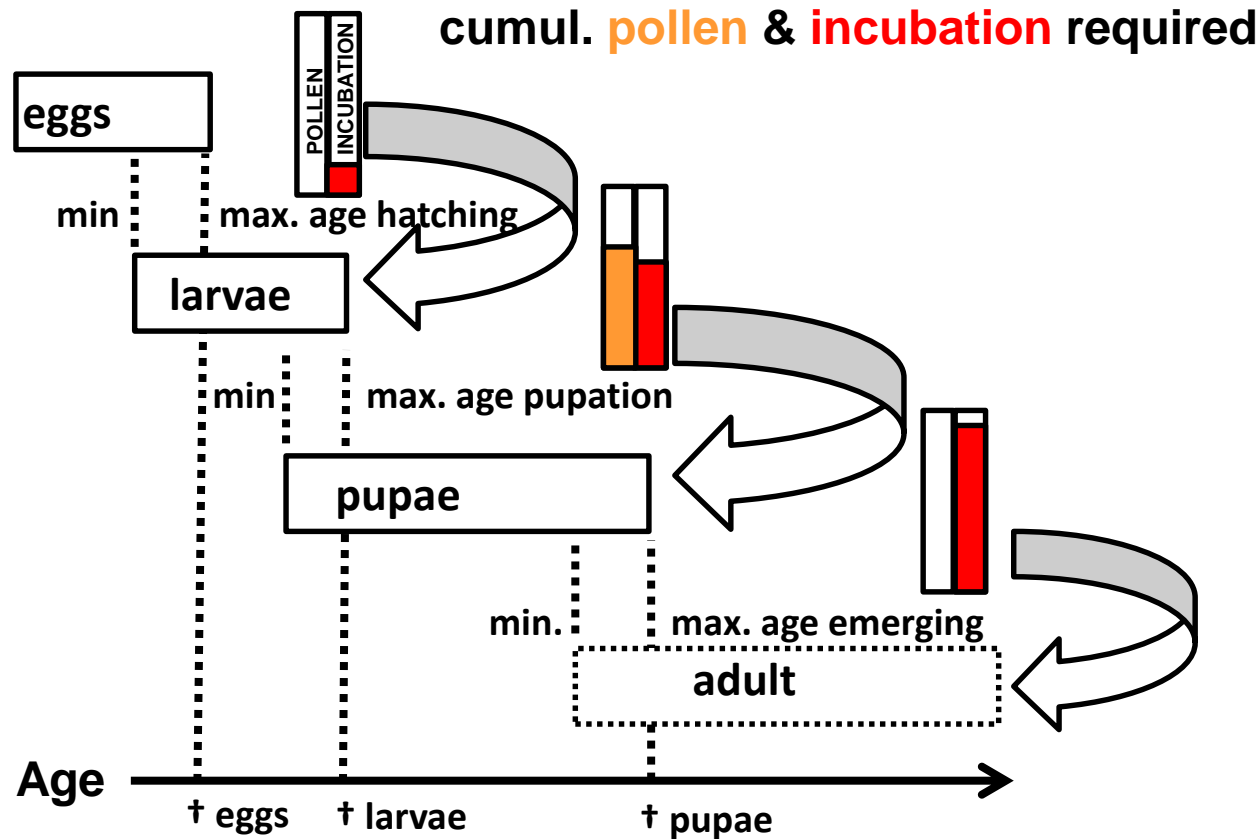
First batch of eggs is laid

Brood needs incubation & feeding

brood development

Brood needs..

- **incubation**
- **feeding pollen**
- **feeding nectar**



Nectar consumption larvae: depends on today's weight gain

Social phase

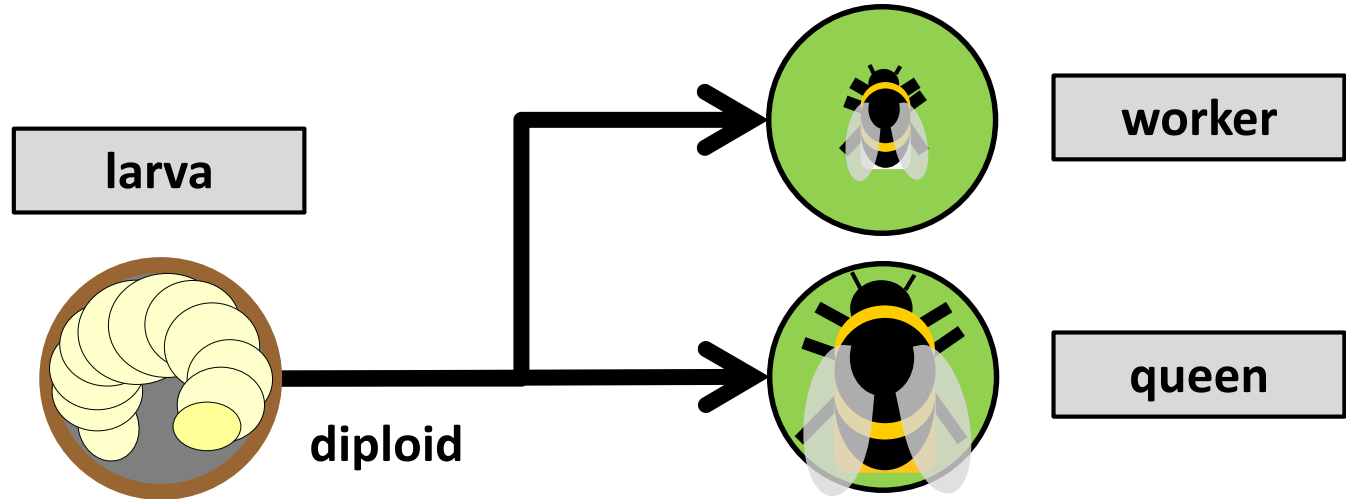


Queen: egg laying

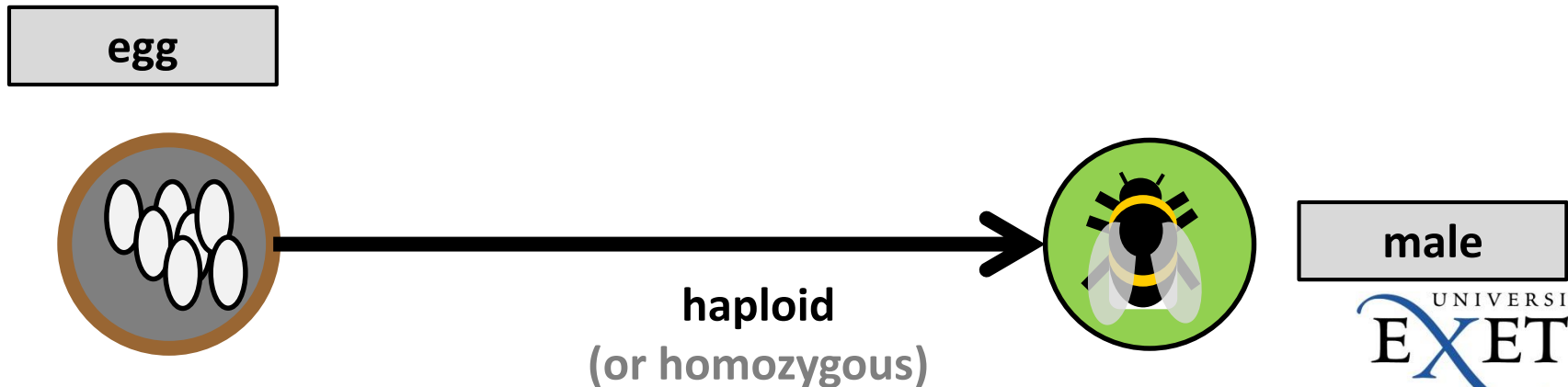
Workers: brood care & foraging

caste determination

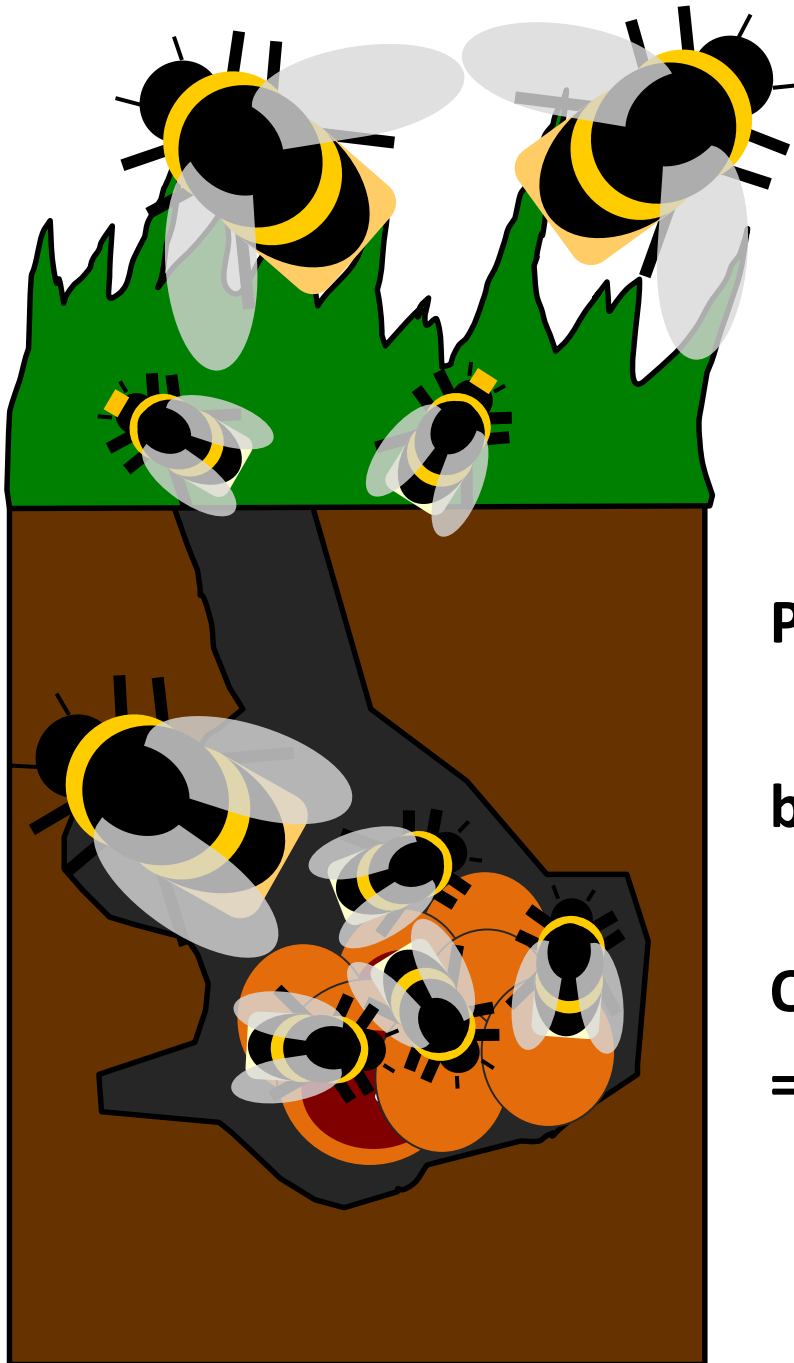
Queen: starts laying diploid eggs => workers



**eventually switches to lay haploid eggs => males
=> increased feeding for diploid larvae => queens**



Reproduction



Productions of males and/or queens

based on Duchateau & Velthuis 1988

**Queen switches to lay haploid eggs
=> triggers production of queens**

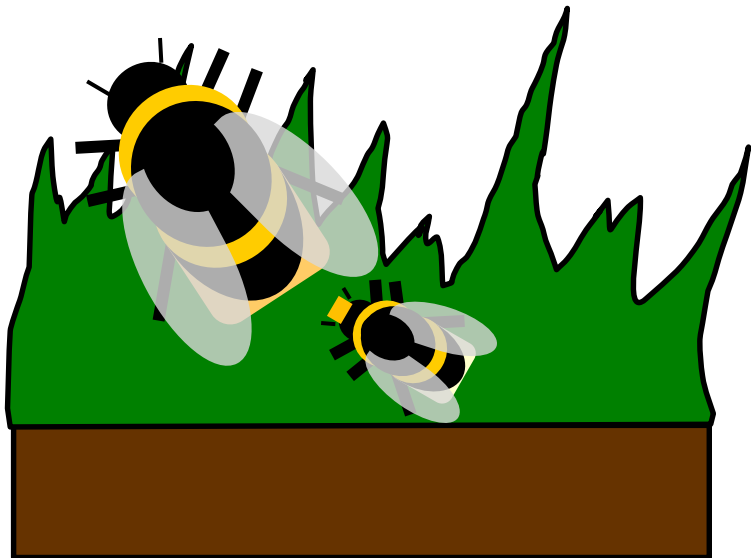
Mating & Hibernation

Adult queens immediately mate with single, random male (from a different colony)

1 locus: allele from male stored in spermatheca

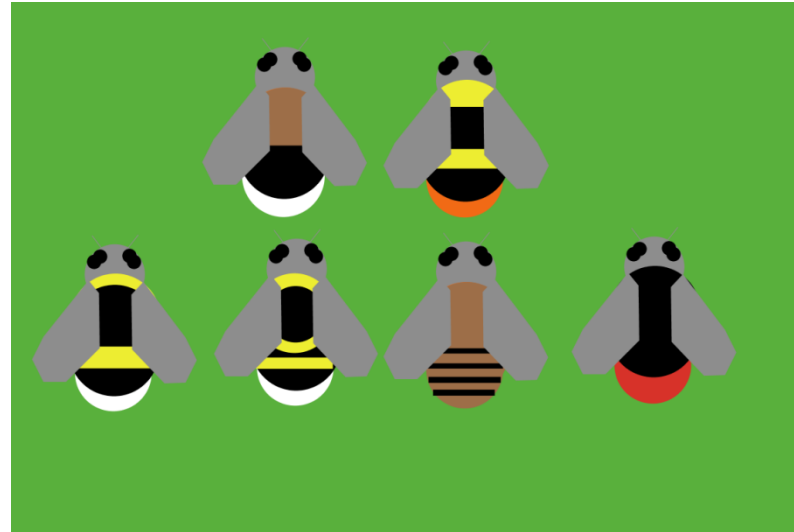
**Optional (if SexLocus? = true):
risk of diploid males**

Mated queens => hibernation



Species

Up to 6 different (UK) species



Species may differ in:

- mean (+-s.d.) date of emergence
- nesting habitat
- development times & weights for workers & queens
- tongue length => preferences for food sources

Overview:

Model Structure

MAIN ELEMENTS

1. SETUP

SETUP Button

- clear memory
- set parameters
- show map
- initialise agents (e.g. bees, food sources, bee species)

2. GO

RUN Button

- run simulations
- daily time steps
- weather related foraging
- seasonal/annual events

(1b) USER INTERACTION

various PANEL Buttons

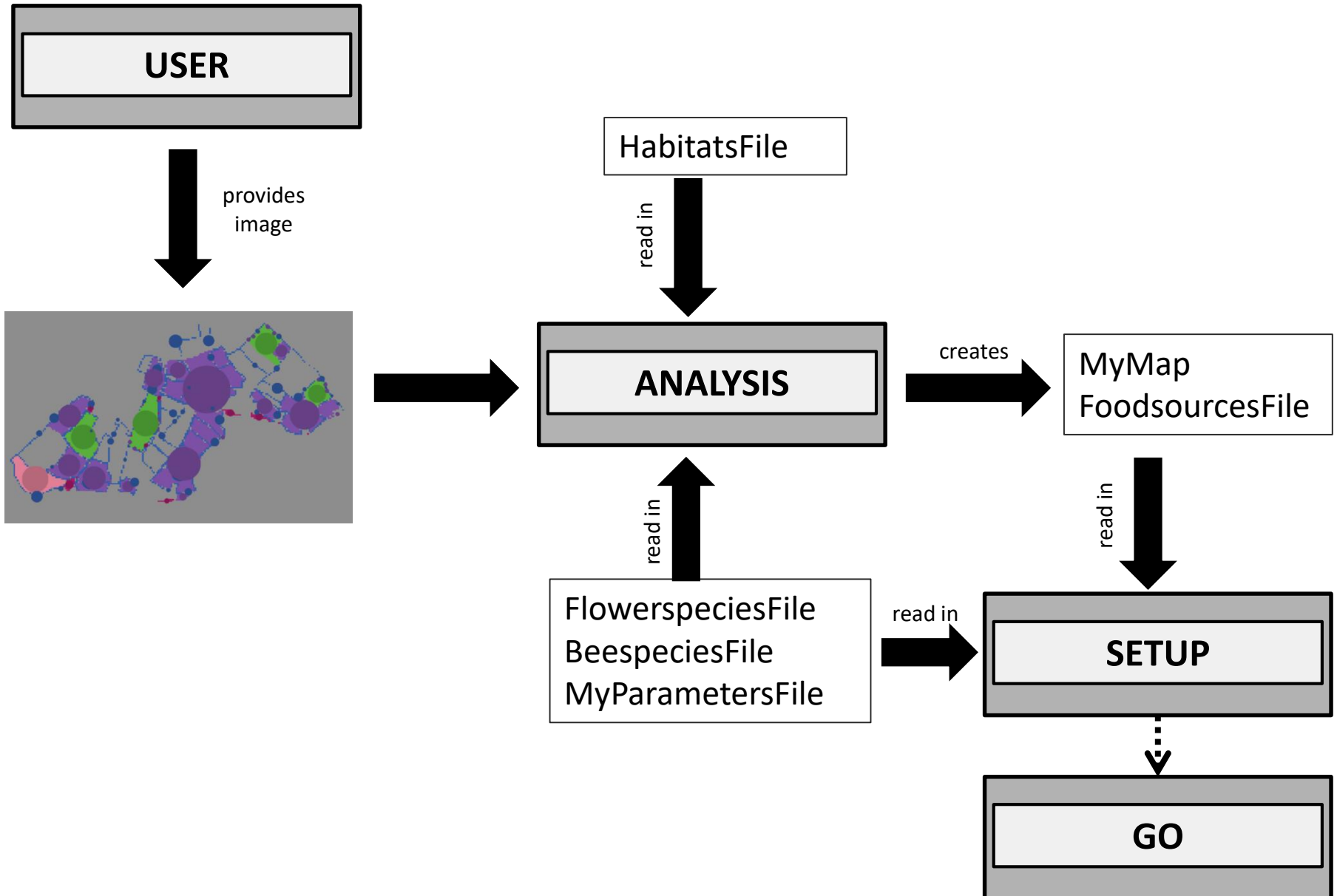
- load/modify map
- change parameter settings
- add stewardship options
- create report
- etc.

(1c) ANALYSIS

UPDATE Button

- Identify food patches on map
- calculate food production
- create FoodsourcesFile, MyMap

INFORMATION FLOW & FILES



BEE-STEWARD FILES

MyMap (IMAGE file; e.g. "_SYSTEM_Example_Farm.png")(optional)

-> representation of the map (may also be defined via a text file)

FoodsourcesFile(TEXT file; e.g. "_SYSTEM_Example_Farm_Foodsources.txt")

-> defines all available food patches (location, size, habitat type etc.)

FlowerspeciesFile (CSV file; e.g. "_SYSTEM_Flowerspecies.csv")

-> defines plants (flowering period, nectar and pollen production etc.)

BeespeciesFile (CSV file; e.g. "_SYSTEM_BumbleSpecies_UK_01.csv")

-> defines bee species (nesting habitat, weights, tongue lengths etc.)

MyParametersFile (CSV file; e.g. "_SYSTEM_Parameters.csv")

-> defines many model parameters (initial queens, input files etc.)

HabitatsFile (CSV file; e.g. "_SYSTEM_Habitats.csv")

-> defines habitats types (plant species, flower densities)

BackgroundImage (image file, e.g. a satellite image)(optional)

-> additional information for the user, no impact on model



Report_name (CSV file)

-> results of a short simulation study, that can be used with "_SYSTEM_My BEE-STEWARD.xlsm" to compare results from two scenarios