

# An IBM to optimize population introductions

## Applications to conservation biology and biological control

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### Propagule pressure and density dependence

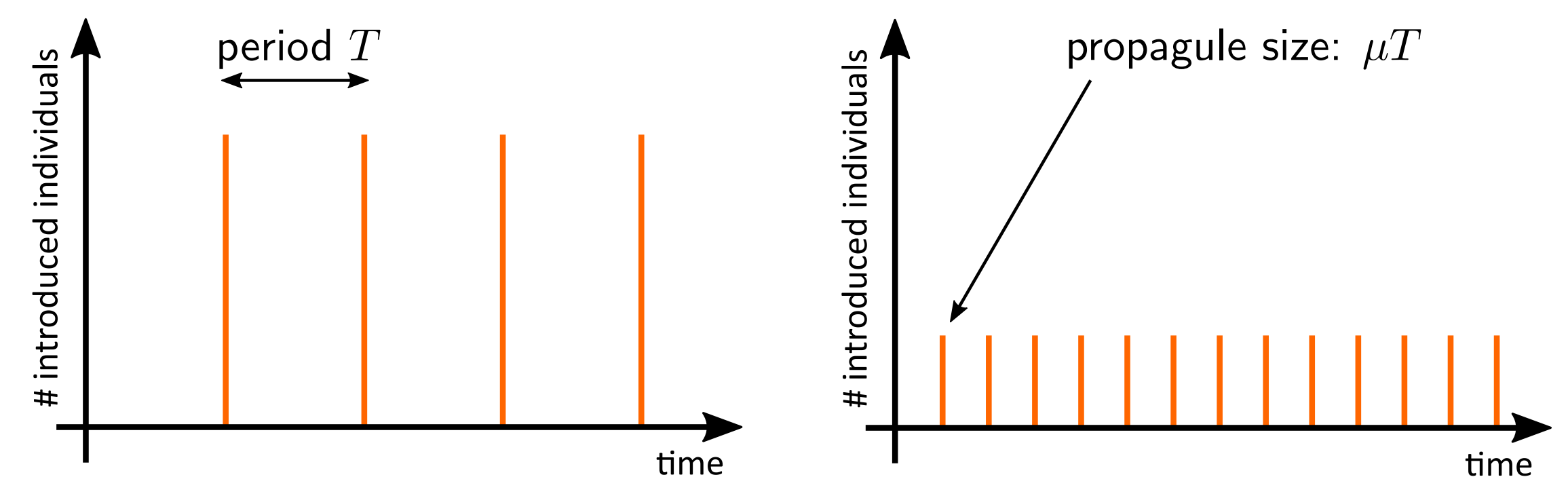
Conservation biology and biological control both involve the **introduction** of **populations** in the environment. These introductions aim to reinforce or **reintroduce** a species for patrimonial/ecological reasons, or to **combat pest** infestations with their natural enemies.

**Propagule pressure** quantifies the overall introduction effort; it encompasses:

- propagule size (number of individuals per introduction)
- propagule frequency (frequency of introductions)
- patterns of introductions (distribution of introductions in time)

A general prediction is that **increasing** propagule **size** or propagule **frequency** favors the **success** of the introduction programme, because both increase the rate of introduction (Simberloff, 2009).

For a **given rate of introduction**  $\mu$ , mathematical models (pulsed differential equations) asserted that **patterns of introduction** interact with **density dependence** in population dynamics.



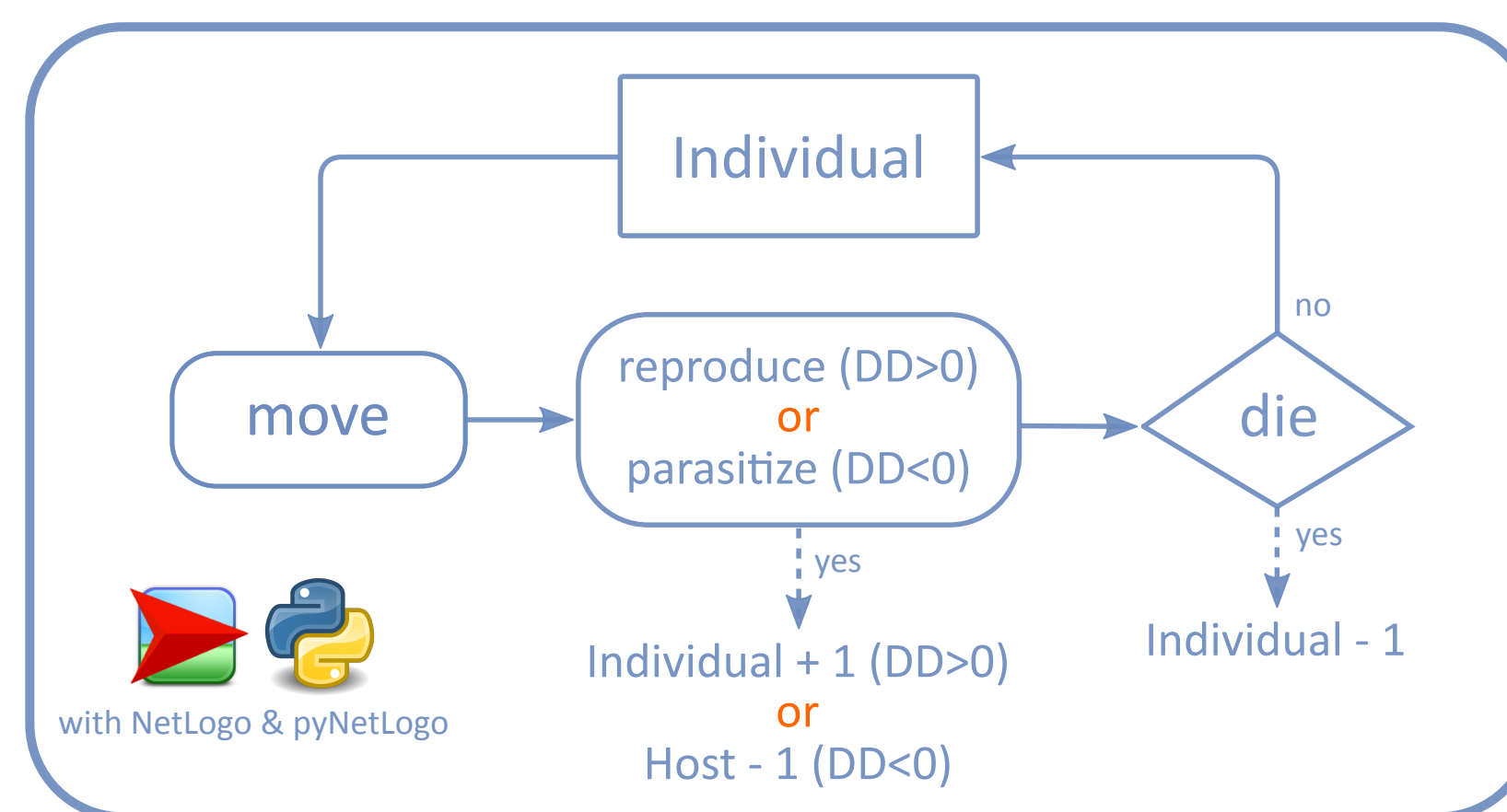
- **Positive** density dependence: **large size** and **rare introductions** are better (Mailleret & Lemesle 2009; Bajeux *et al.* 2017)
- **Negative** density dependence: **small size** and **frequent introductions** are better (Nundloll *et al.* 2010a, 2010b)

### Positive density dependence: reintroduction

- one population
- random movements of individuals
- density dependent **reproduction**: probability of reproducing at each time step increases with  $N$  (# neighboring conspecifics)

$$P(\text{repro}) = 1 - \exp(-m_s N)$$

- **objective**: **time to establishment** ( $p_{\pm} = 50\%$ )



### Negative density dependence: biocontrol

- host (pest) and parasitoid populations
- hosts still, random movements of parasitoids
- interference competition in **parasitism**: probability of parasitising a host at each time step decreases with  $N$

$$P(\text{parasit}) = \exp(-c_i N)$$

- **objective**: **time to suppress host pop.** by 90%

**Same introduction policies in both models**: every  $T$  unit time, introduce  $X_T$  individuals, with  $X_T$  drawn from a Poisson law:

$$X_T \sim \mathcal{P}(\mu T)$$

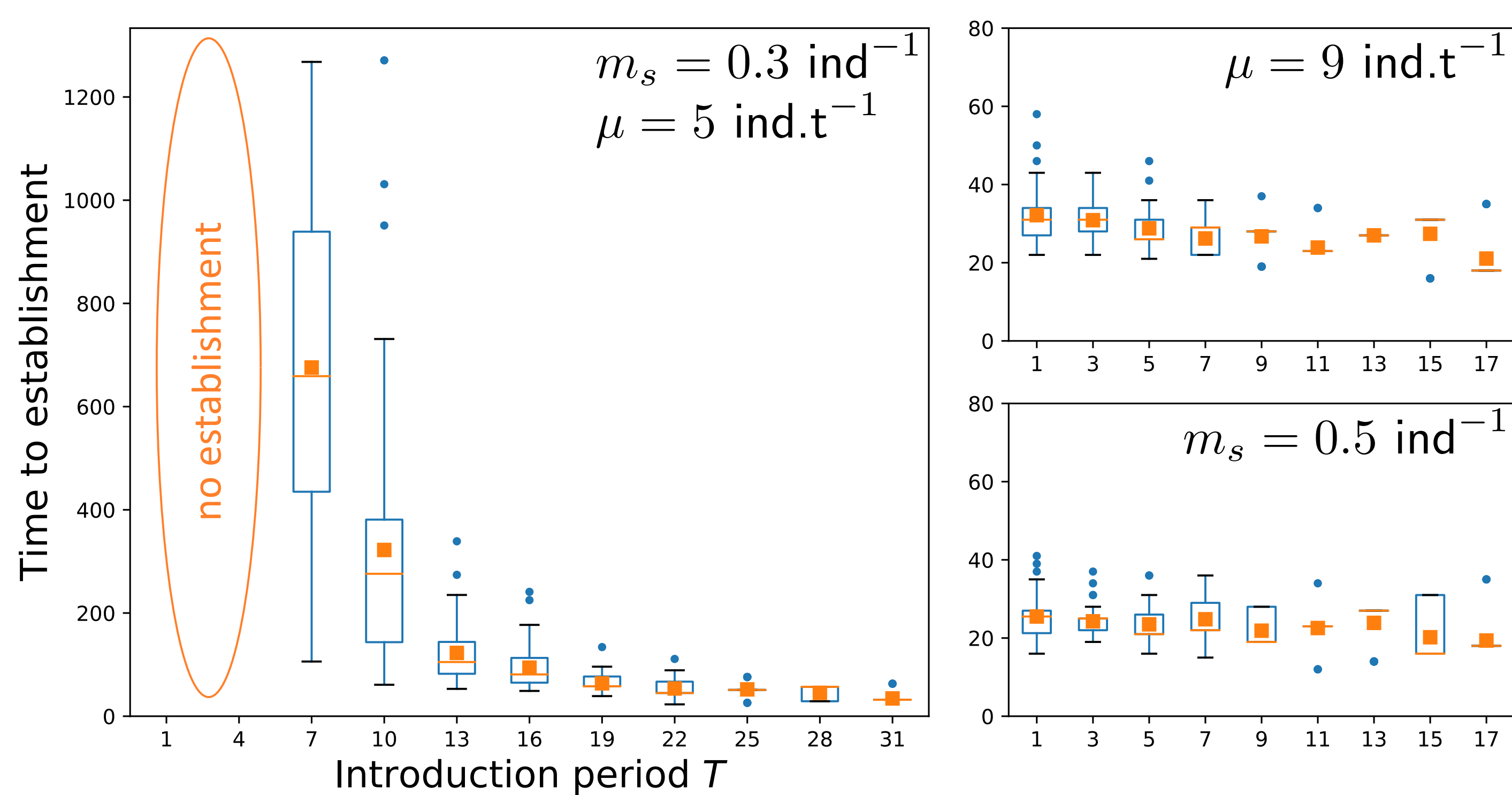
$\mu$  is the **introduction rate** of individuals or parasitoids

$T$  is the **period** between two **introduction** events

⇒ compute the **time** to achieve the **objective** (Monte Carlo approach)

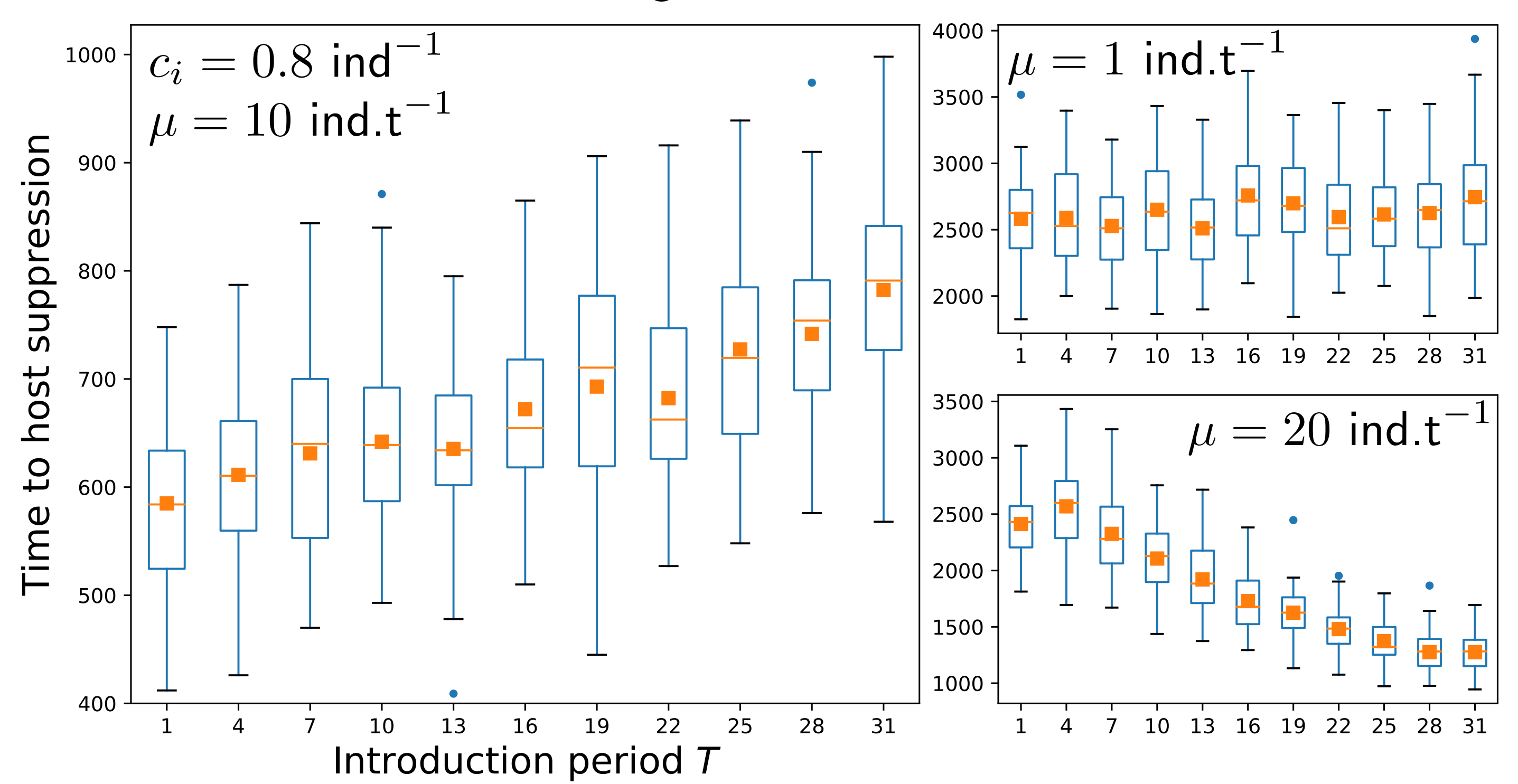
### Results

Reintroduction scenario



- **rare** and **large** introductions lead to faster pop. establishment
- **small** and **frequent** introductions can even **fail**
- **effect fades out** for large  $\mu$  or smaller positive density dep.

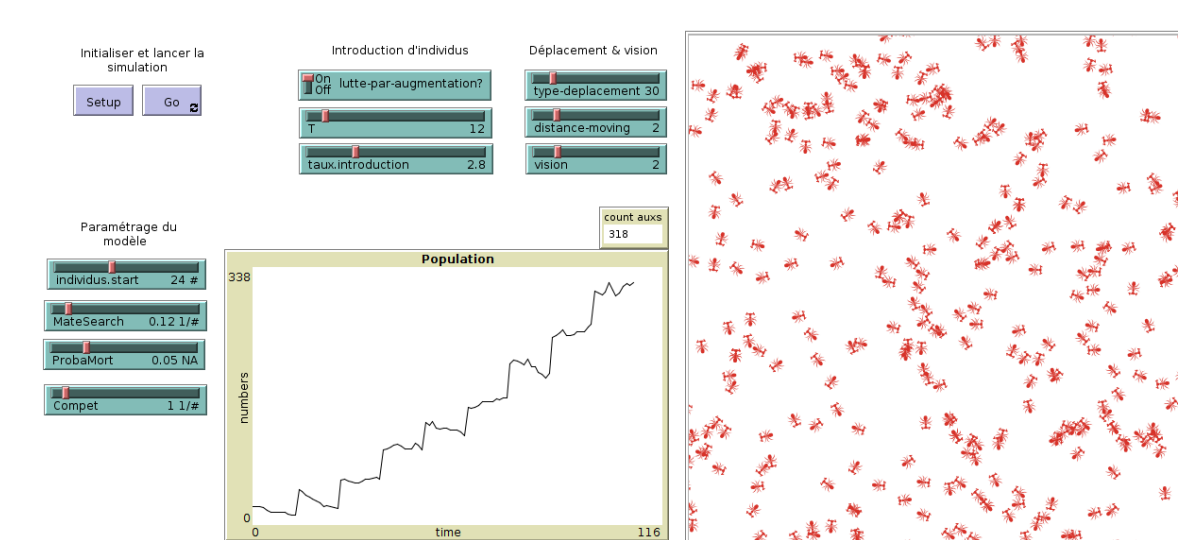
Biological control scenario



- **small** and **frequent** introductions allow faster host suppression
- **effect fades out** for small  $\mu$  or smaller competition (not shown)
- **effect is reversed** for large  $\mu$ , rare and frequent intro. more efficient

### Conclusions

Trends **predicted** by theory were **identified** in stochastic IBM simulations. Yet these trends only show up for **limiting**  $\mu$  or **strong density dependence**. **Emerging patterns** have also been detected.



An attractive easy-to-use platform to communicate & explore the influence of introduction patterns on pop. dyn.

### References

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