Mathematical modeling of host change hypothesis in avian brood parasitism

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Outline

- Motivation of this research
- The model
- Simulation and Results
- Conclusion・Future Work

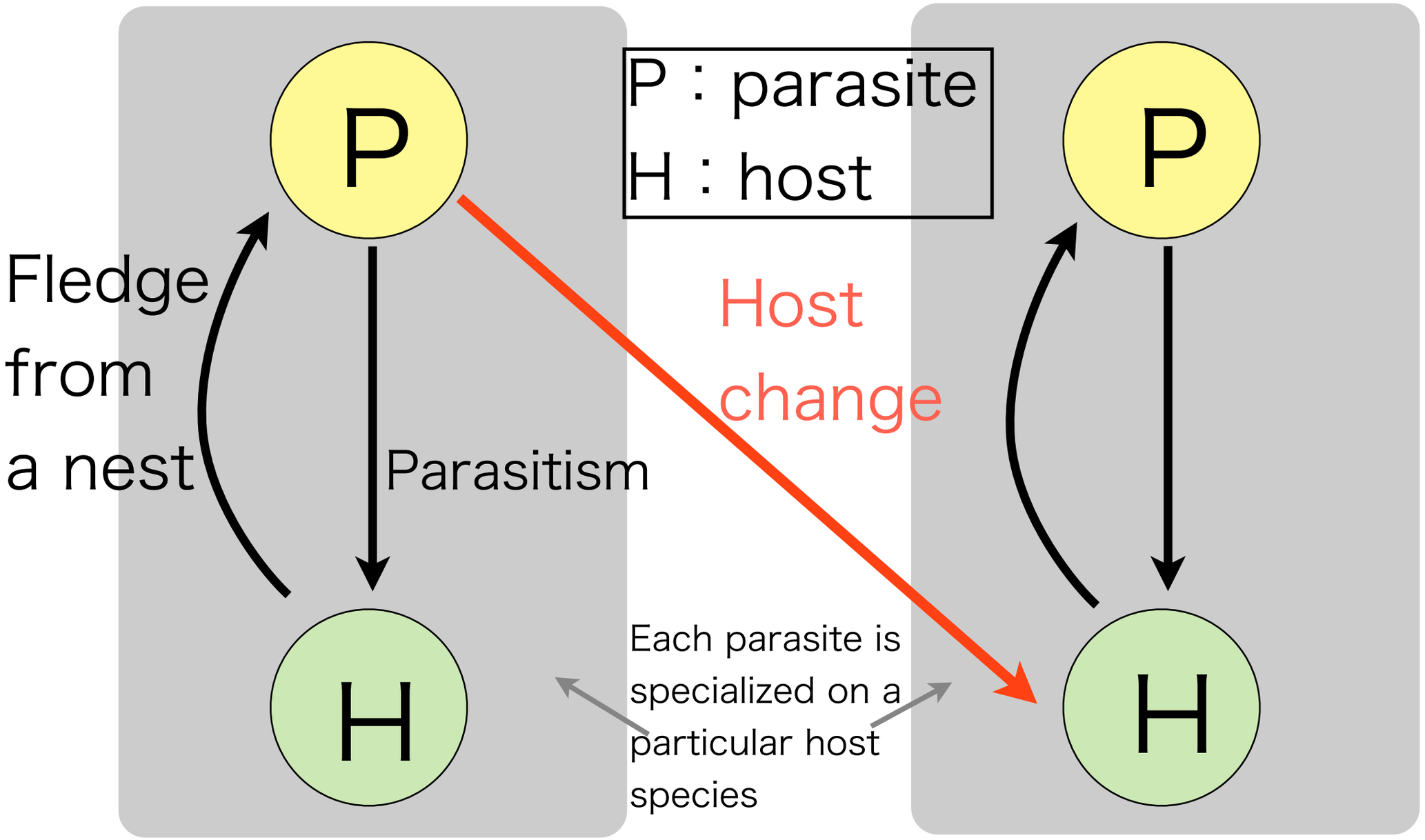
Motivation of this research

Azure-winged magpie, holding a cuckoo chick in the nest

「Cuckoo」 ・Toshiyuki Yoshino・Bunitisogo Publication

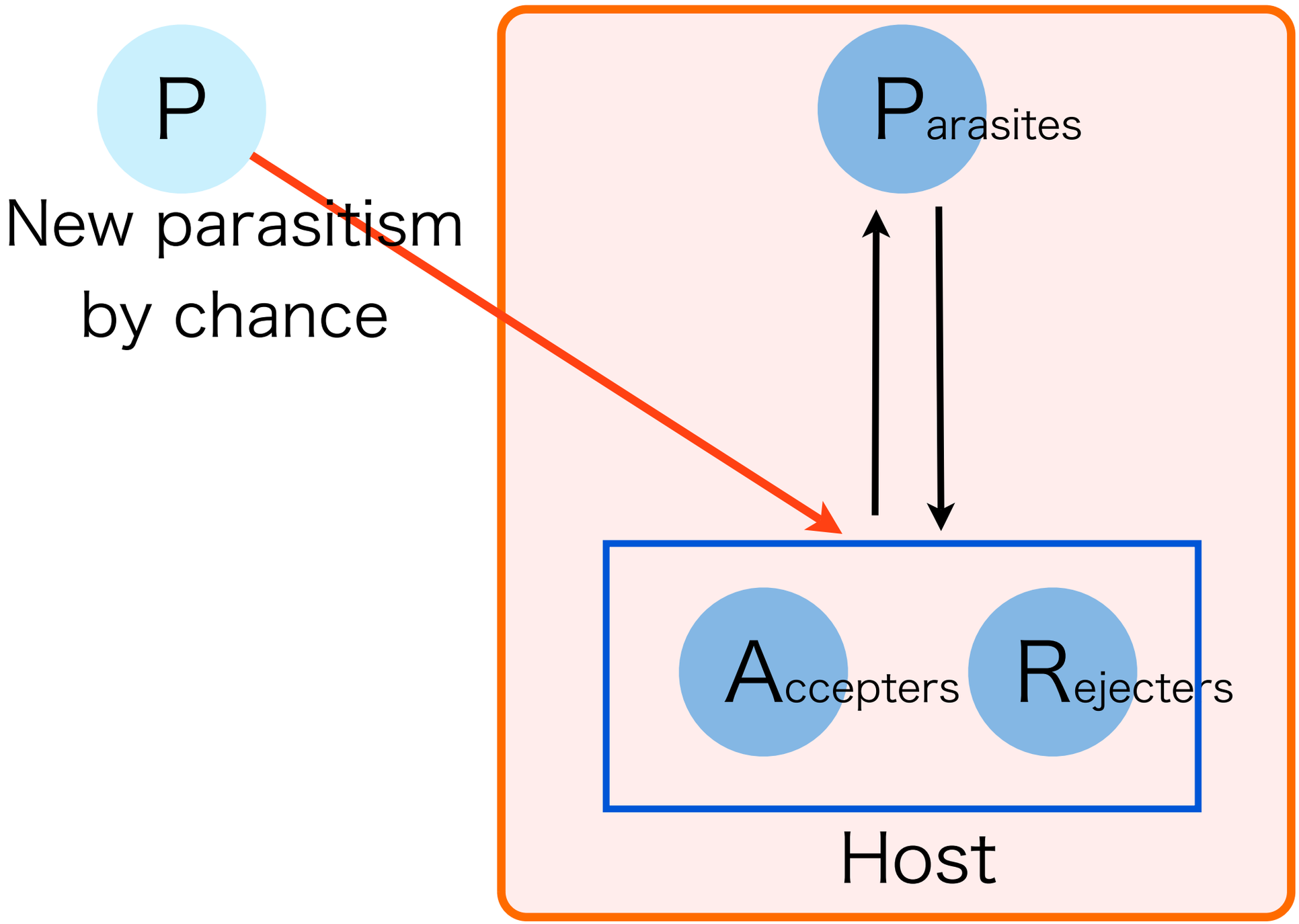
The previous hosts are great reed warblers and bull-headed shrikes

Host change hypothesis



“The parasite might persist by changing target host species before the present host establishes defense against parasitism at a high level.”

Three population model



Deterministic model

○ : Population density

$$P_{t+1} = s_P P_t + (1 - e^{-aP_t}) A_t \Gamma$$

$$A_{t+1} = \frac{k}{k + A_t + R_t} [s_H + f e^{-aP_t}] A_t$$

$$R_{t+1} = \frac{k}{k + A_t + R_t} [s_H + \epsilon f] R_t$$

- Easy to analyze
- Not appropriate to study low population density

Stochastic approach is needed

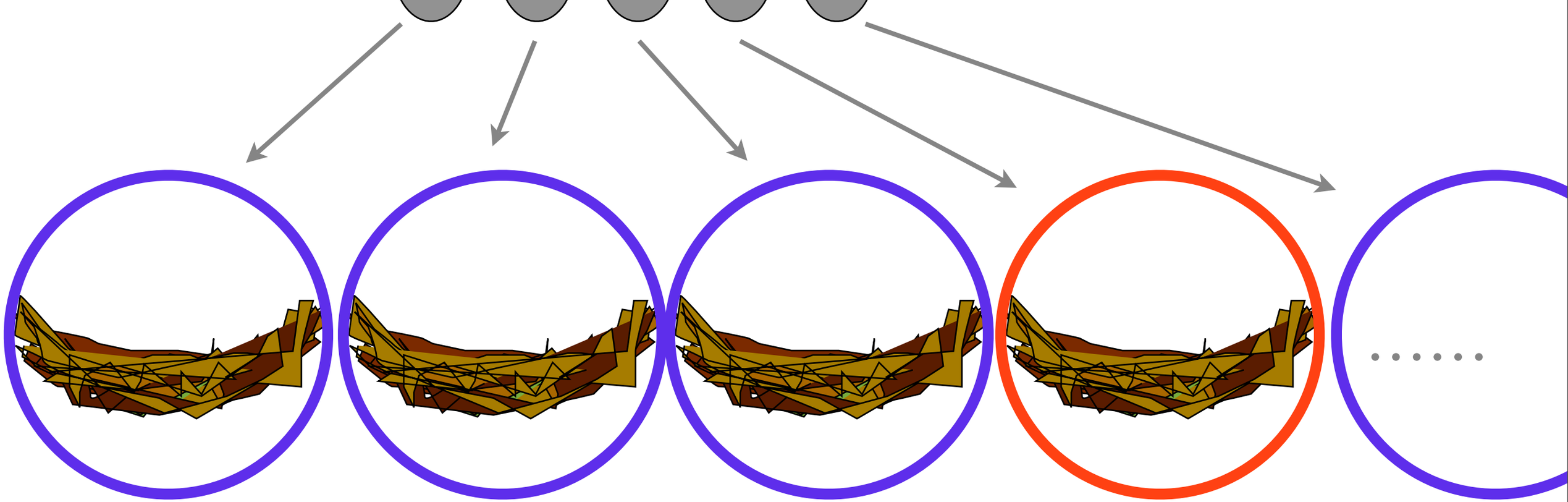
The model

In the beginning

Accepter : ○
Rejecter : ○

Lay C eggs

♀



The model

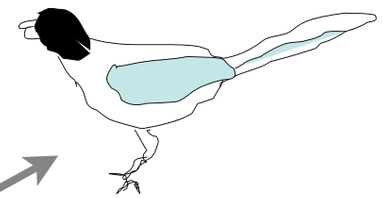
In accepter's nest

cuckoo chick

cuckoo egg is accepted

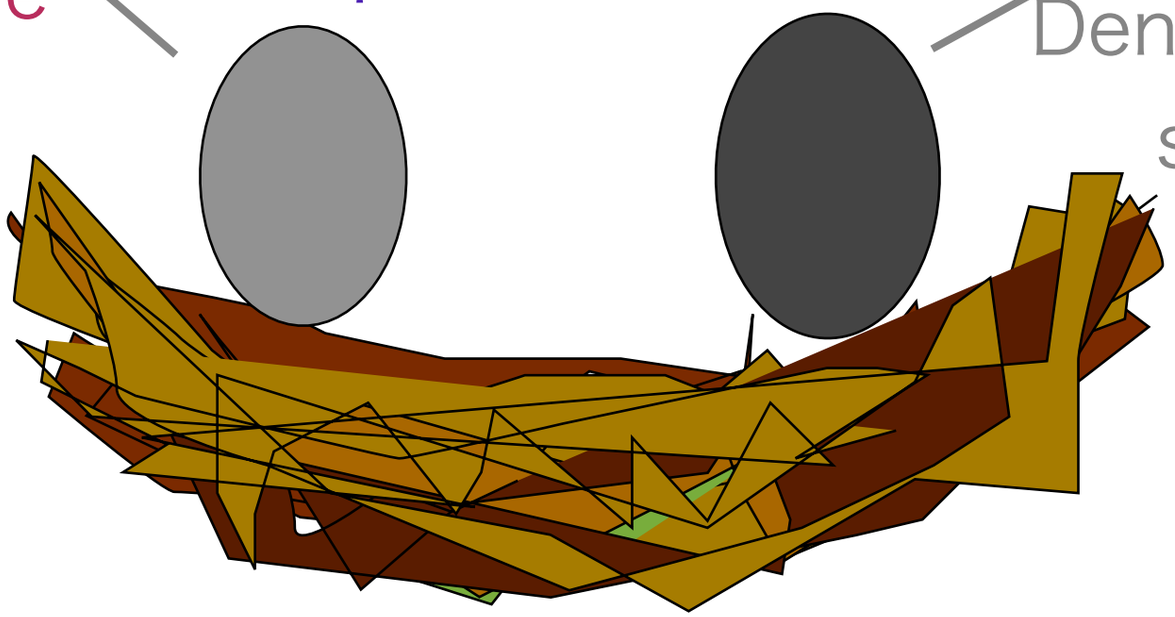
survive

host chick



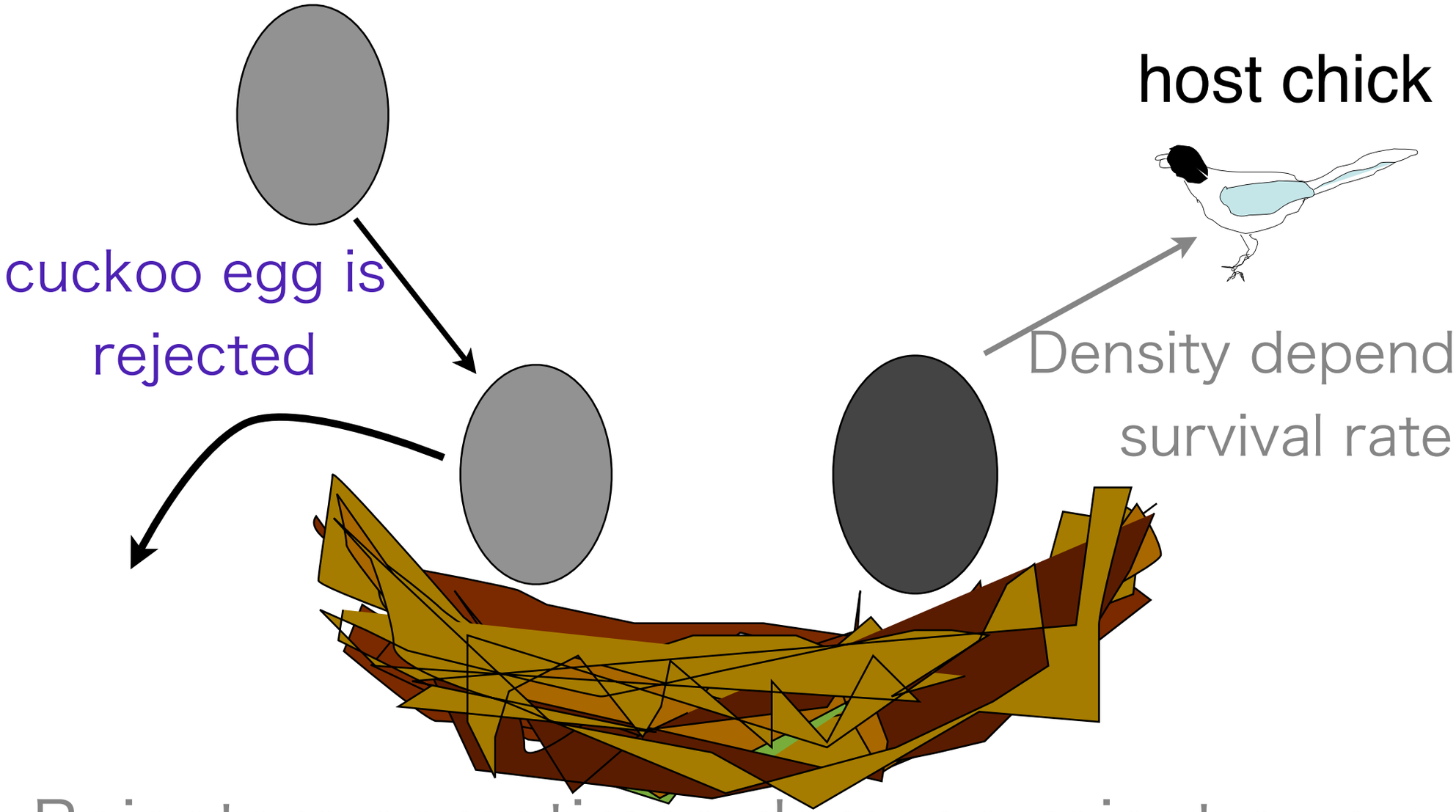
survive

Density dependent survival rate



The model

In rejecter's nest



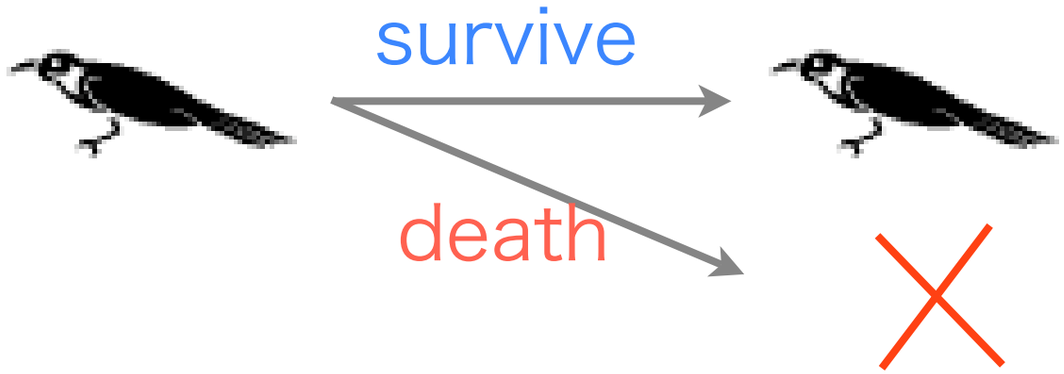
Rejecters sometimes damage reject own eggs

(Rejection cost $\epsilon < 1$)

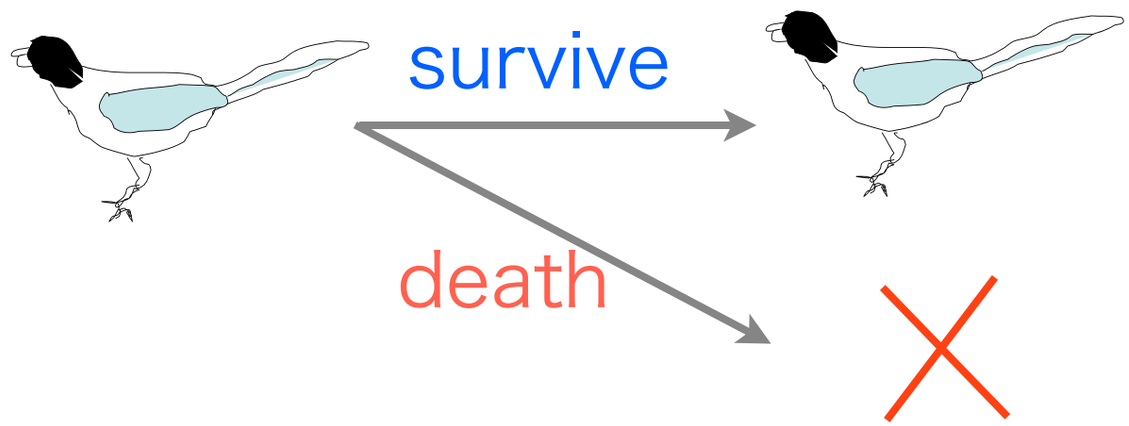
The model

about adult

parasite



host

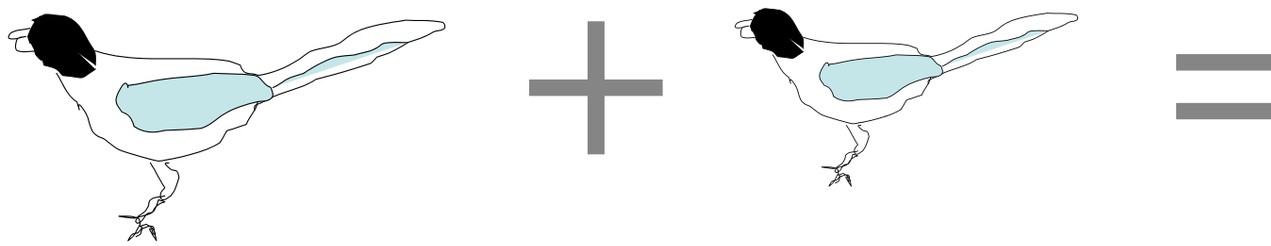


Adult parasite and host survive with certain probability to the next year

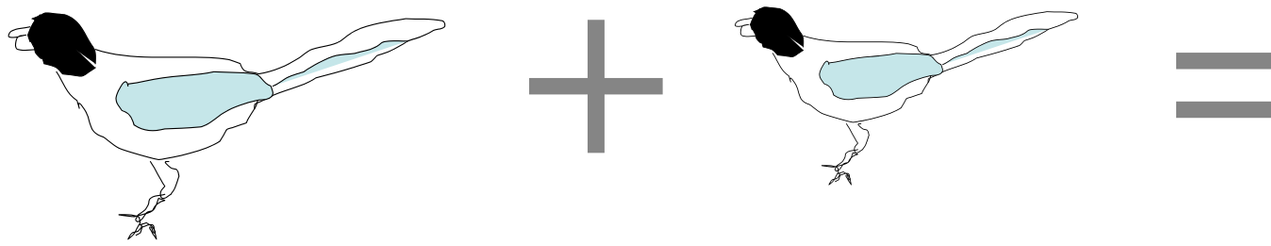
The model

adult young Number of individuals of next year

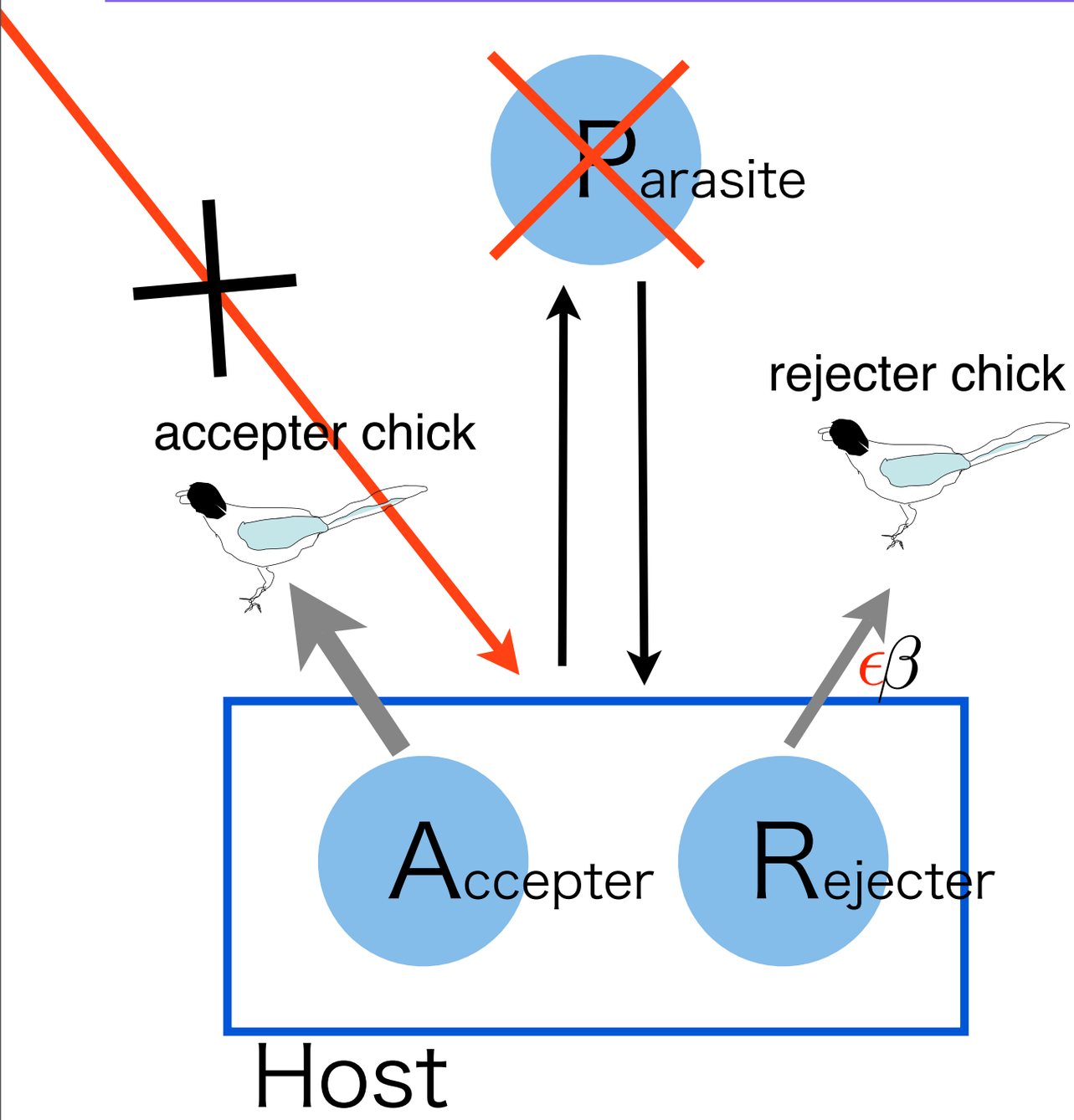
Accepter



Rejecter



Simulation(P_0=0)

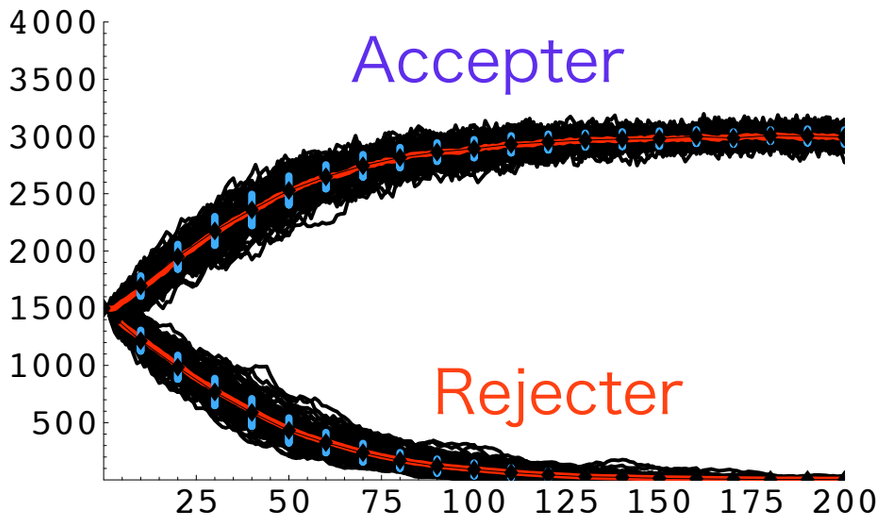


- Reproductive success of rejecters is 5% less than that of accepters
- Rejecters will eventually disappear

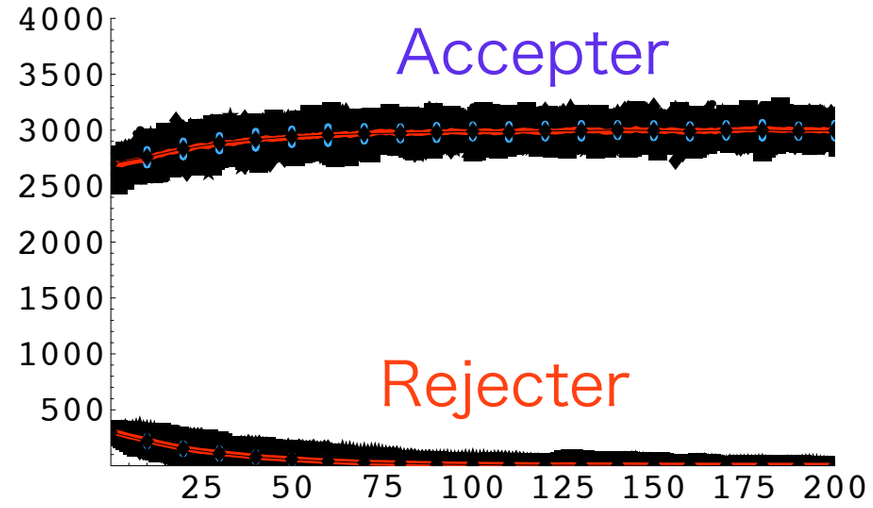
cost : $\epsilon = 0.95$

Simulation(P_0=0)

r_0=0.5

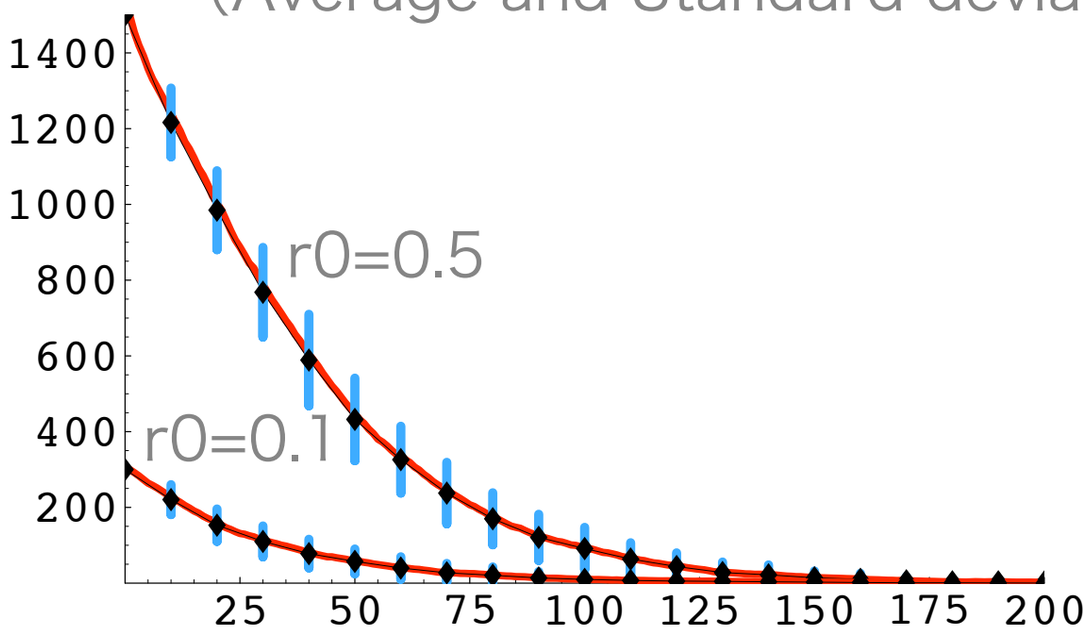


r_0=0.1



Number of Rejecter individuals

(Average and Standard deviation)



r_0 : initial frequency of rejecter

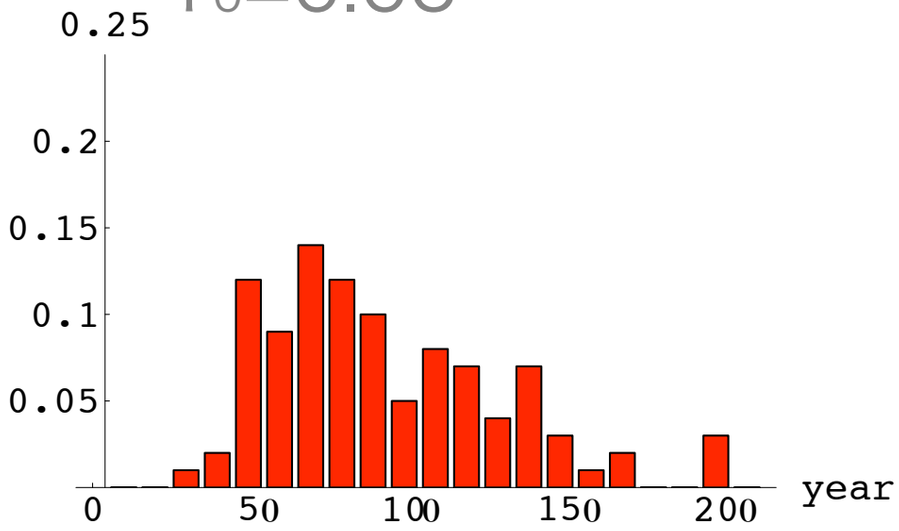
Host carrying capacity~3000

cost : $\epsilon = 0.95$

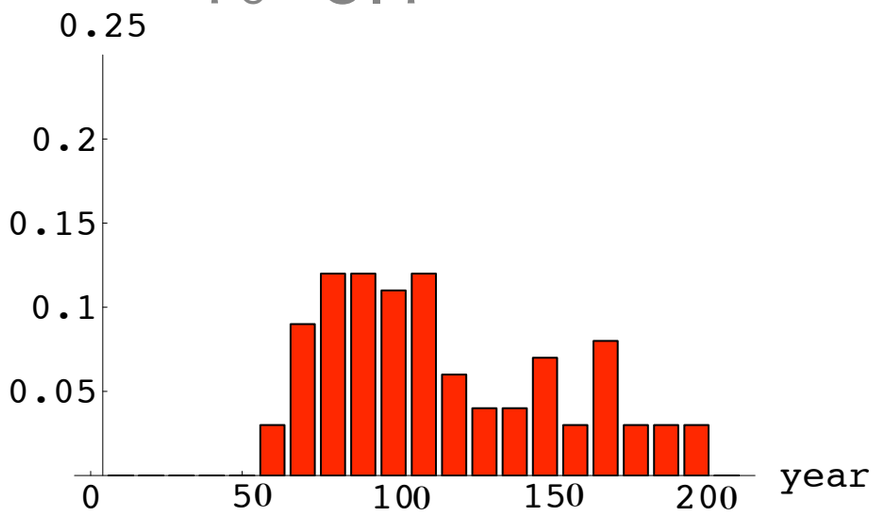
Simulation

The distribution of the time when rejecters went extinct

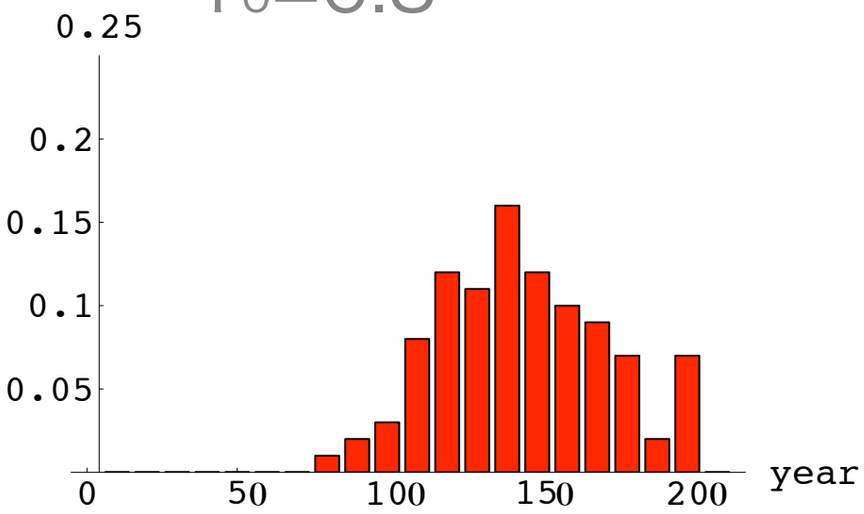
r_0=0.05



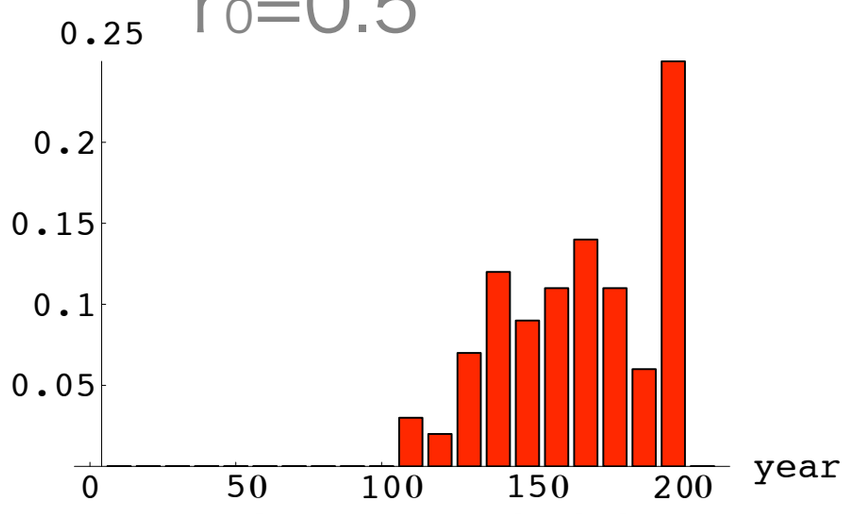
r_0=0.1



r_0=0.3

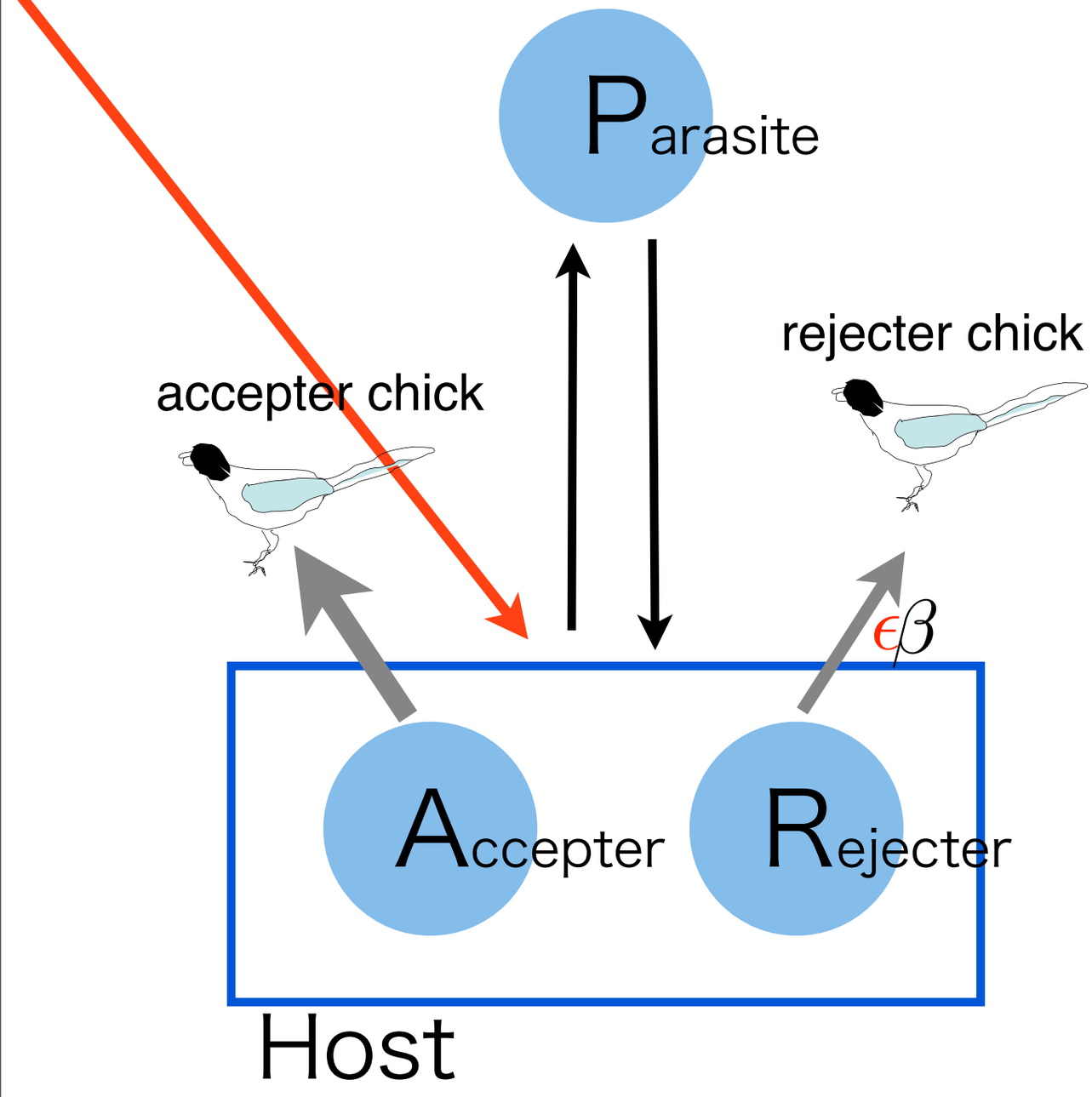


r_0=0.5



Due to stochastic rejecters can go extinct quickly or slowly

Simulation($P_0=1$)

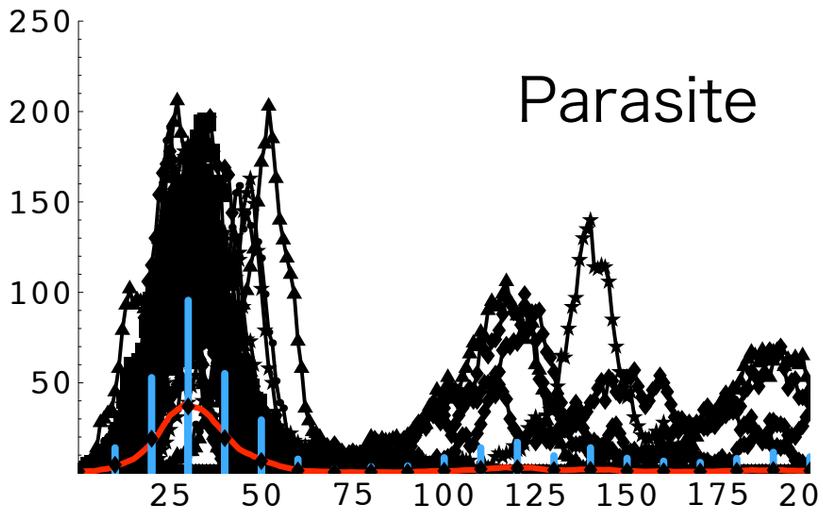


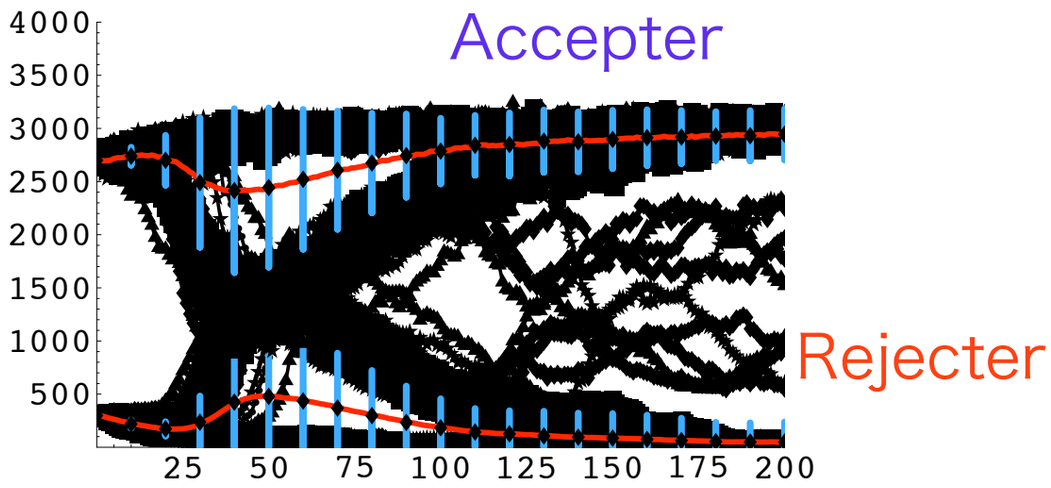
- One parasite switches to new host

cost : $\epsilon = 0.95$

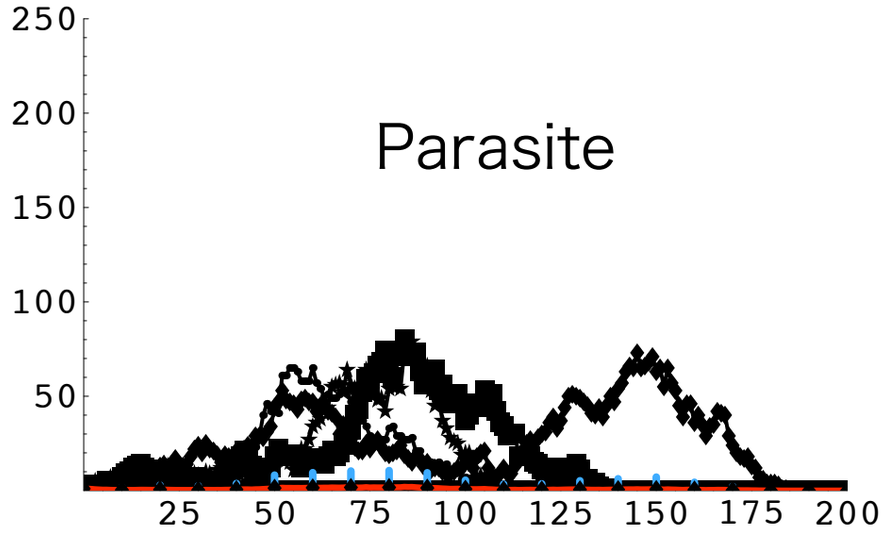
Simulation (P_0=1)

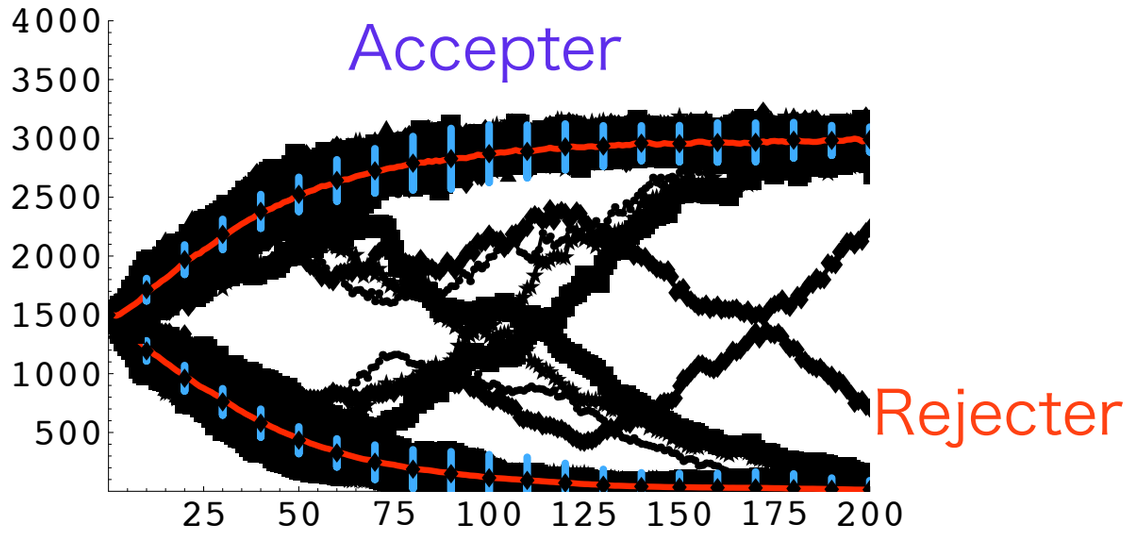
r_0=0.1





r_0=0.5



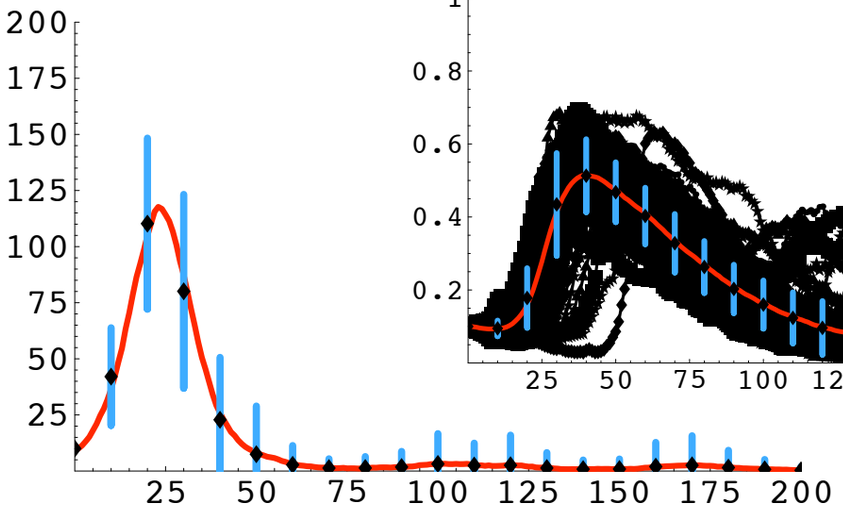


In smaller frequency of rejecters, parasite increase lapidly

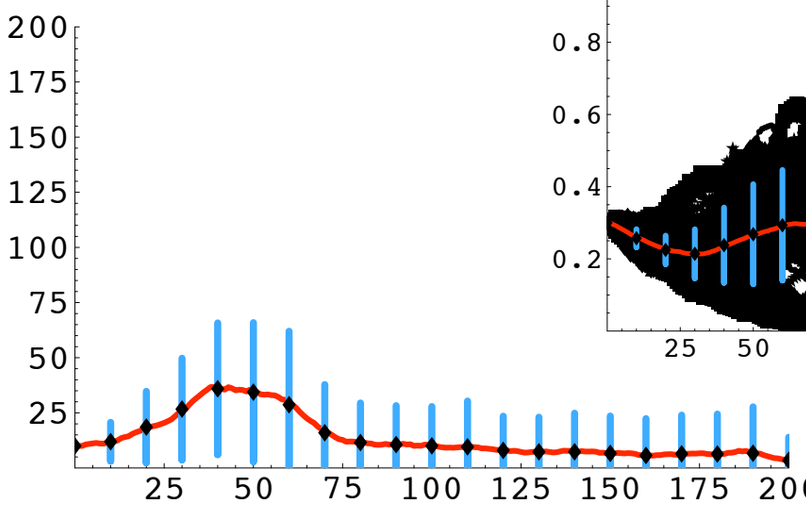
Simulation (Parasite)

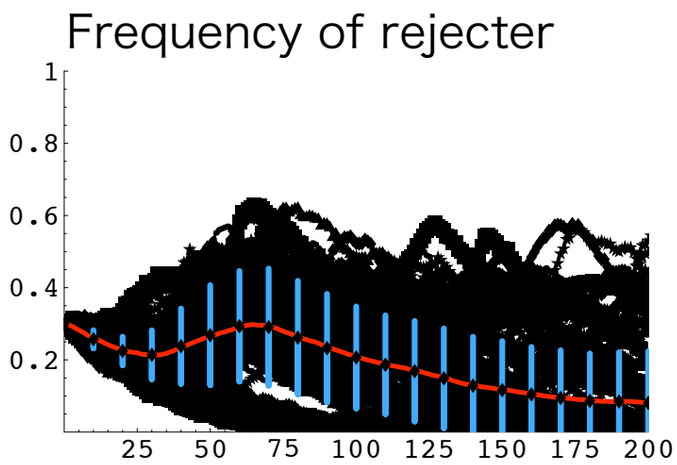
Number of Parasite individuals （Average and Standard deviation ）

r_0=0.1

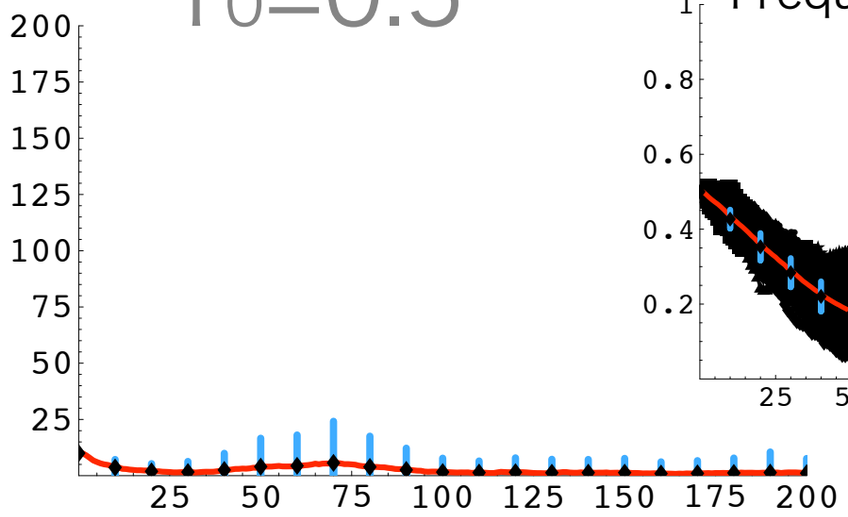


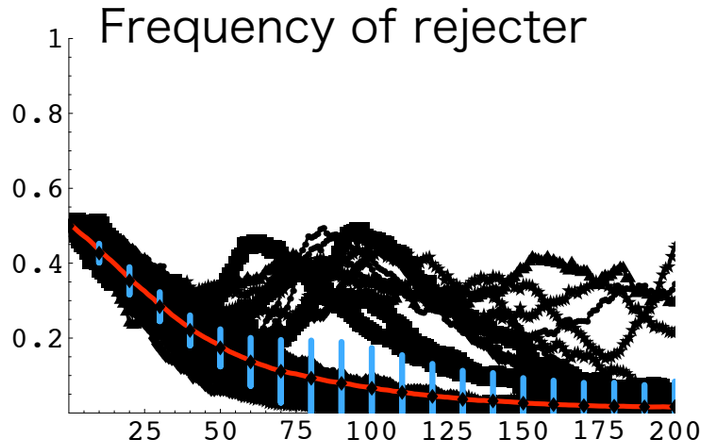
r_0=0.3





r_0=0.5



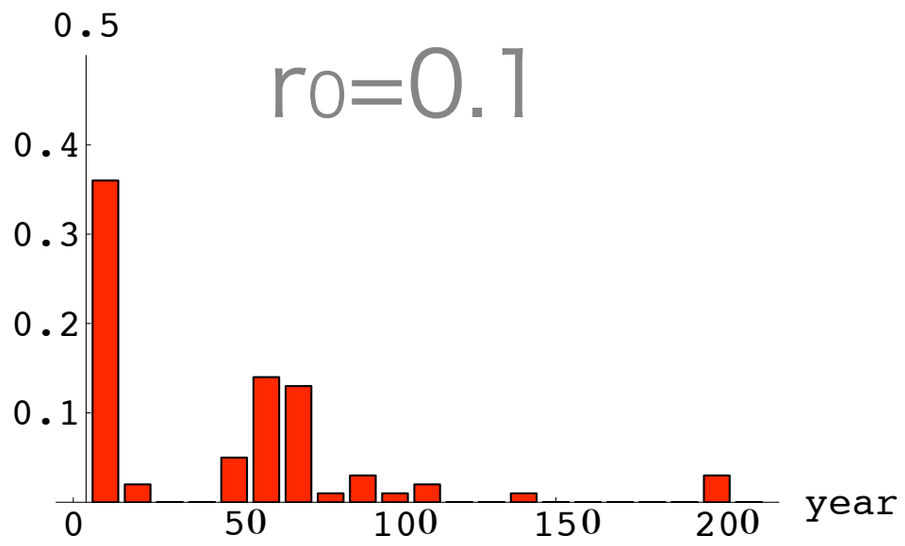


P_0=1

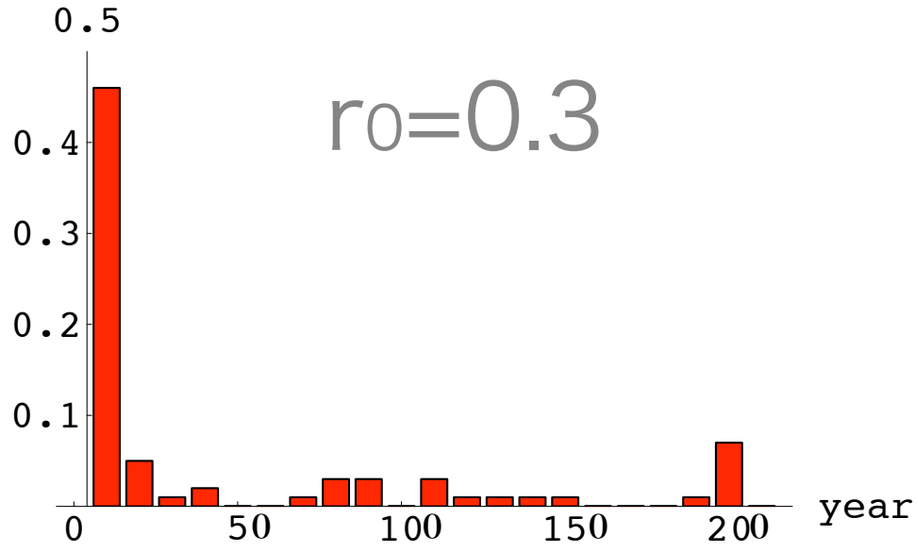
Simulation (Parasite)

The distribution of the time when parasites went extinct

r_0=0.1

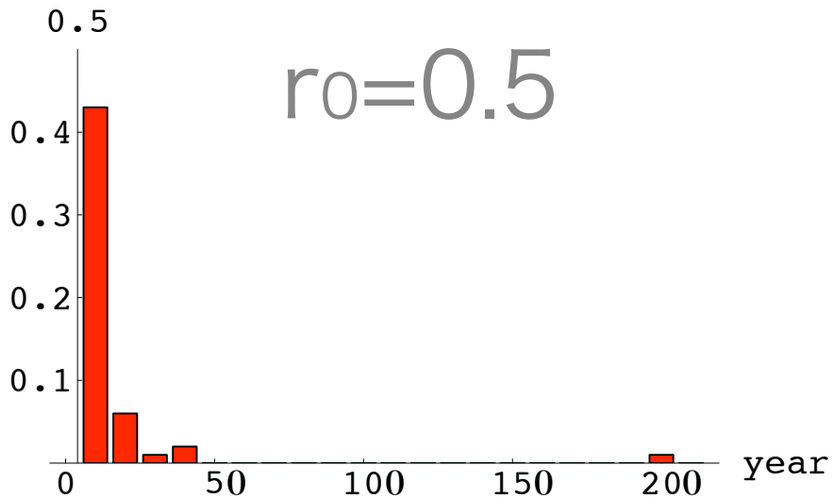


r_0=0.3



P_0=1

r_0=0.5



In r0=0.3,I know there are parasites survive for long time

Conclusion

- A stochastic individual dynamics of three populations is constructed
- Initial number of parasites and frequency of rejecters have influence to success parasitism
- Parasites can survive for long time in middle frequency of rejecters

Future Work

- Extend the model to include more than two host species
- Study the pattern of successful host change by a small number of parasites
- Mathematical analysis of the stochastic dynamics by linearizing the stochastic process
- Spatial structure