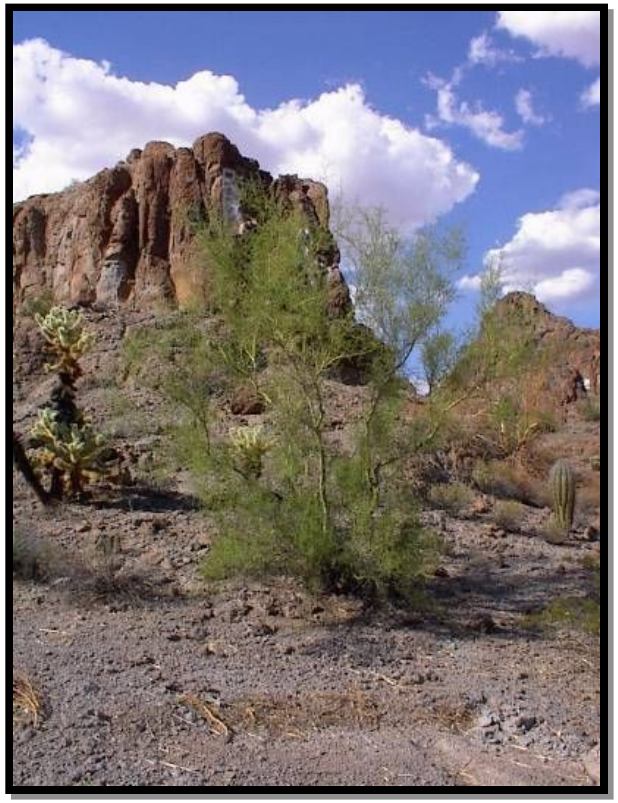
Facilitation and competition in the desert: saguaro cactus and Palo Verde trees

- **Guilherme Casas Gonçalves** (*University of São Paulo, Mathematics Institute, Brazil)*
- **Lucas Paoliello de Medeiros** (*University of São Paulo, Ecology Department, Brazil)*
- **Ludmila Rattis** (*University of Campinas, Graduate School of Ecology, Brazil)*
- **Maria Cecilia de Lima e Sá De Alencar Rocha** (*Federal Uni. Bahia, Biology Institute, Brazil)*
- **Nerea Abrego** (*University of the Basque Country, Dept. Plant Biology and Ecology, Spain)*
- **Susana Contreras** (*Universidad de los Andes, Dept. Biomedical Engineering, Colombia)*

INTRODUCTION OF TARGET SPECIES



Palo Verde tree
Cercidium floridum

Saguaro cactus
Carnegiea gigantea

INTRODUCTION OF TARGET SPECIES

Palo Verde tree
Cercidium floridum

Saguaro cactus
Carnegiea gigantea

DESCRIPTION OF THE ENVIRONMENT

Desert

- Water limitations
- Sun exposure
- Freezing
- Predation
- Wind

INTRODUCTION OF THEIR INTERACTIONS

- Nurse plants

  protection against such adverse conditions

FACILITATION

- Water stress and nutrients

COMPETITION

POPULATION DYNAMICS BASED ON LITERATURE

Saguaros growing under Palo Verde tree

Saguaros that have killed a Palo Verde tree

THE MODEL


- Species-1 needs species-2 to survive in a part of its life-cycle


- Young species-1 consumes the resources that species-2 does not use


- Old species-1 competes with species-2 and kills it

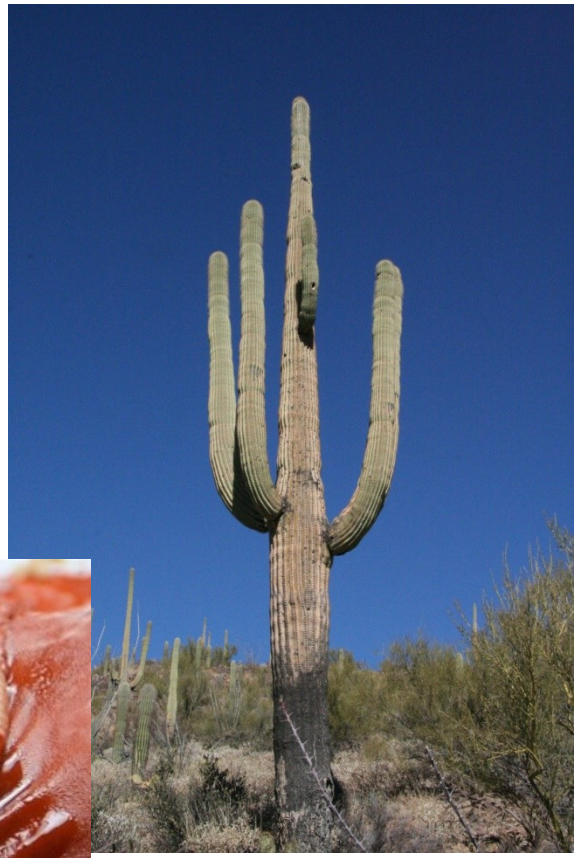
- Species-1 behaves as a parasite!

But not any parasite...

As the killer cacti can survive for very long!!

But not just any parasite…

As the killer cacti can survive for very long!!



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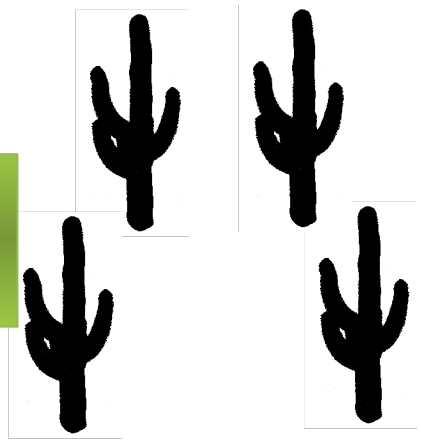

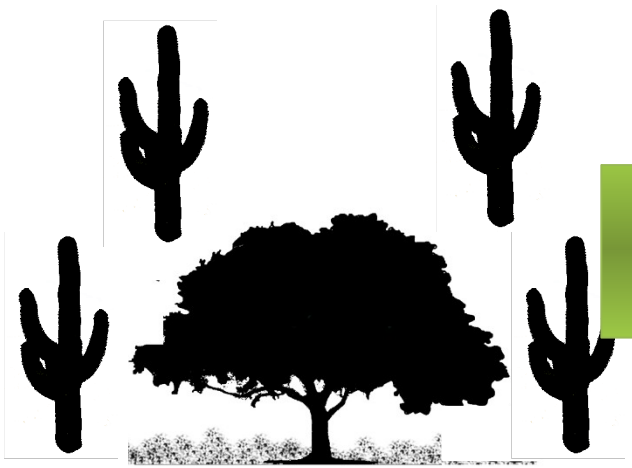

PS
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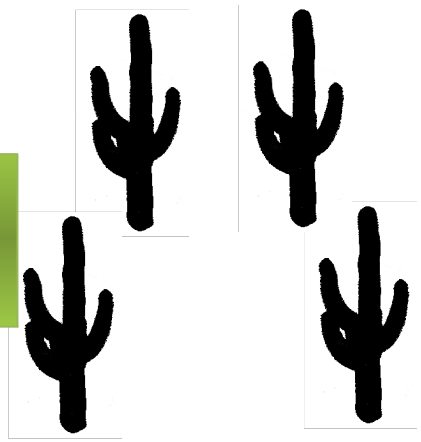

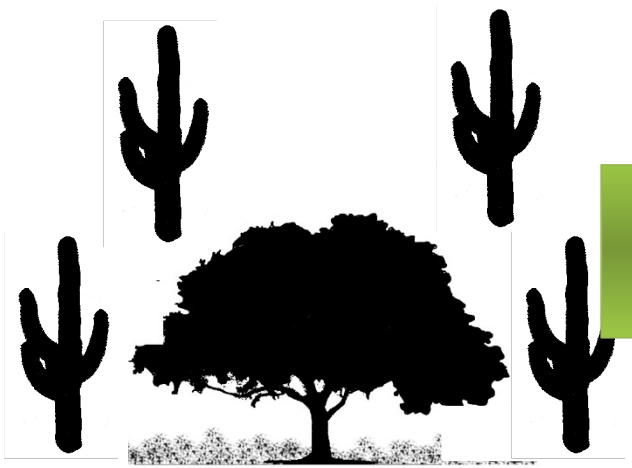

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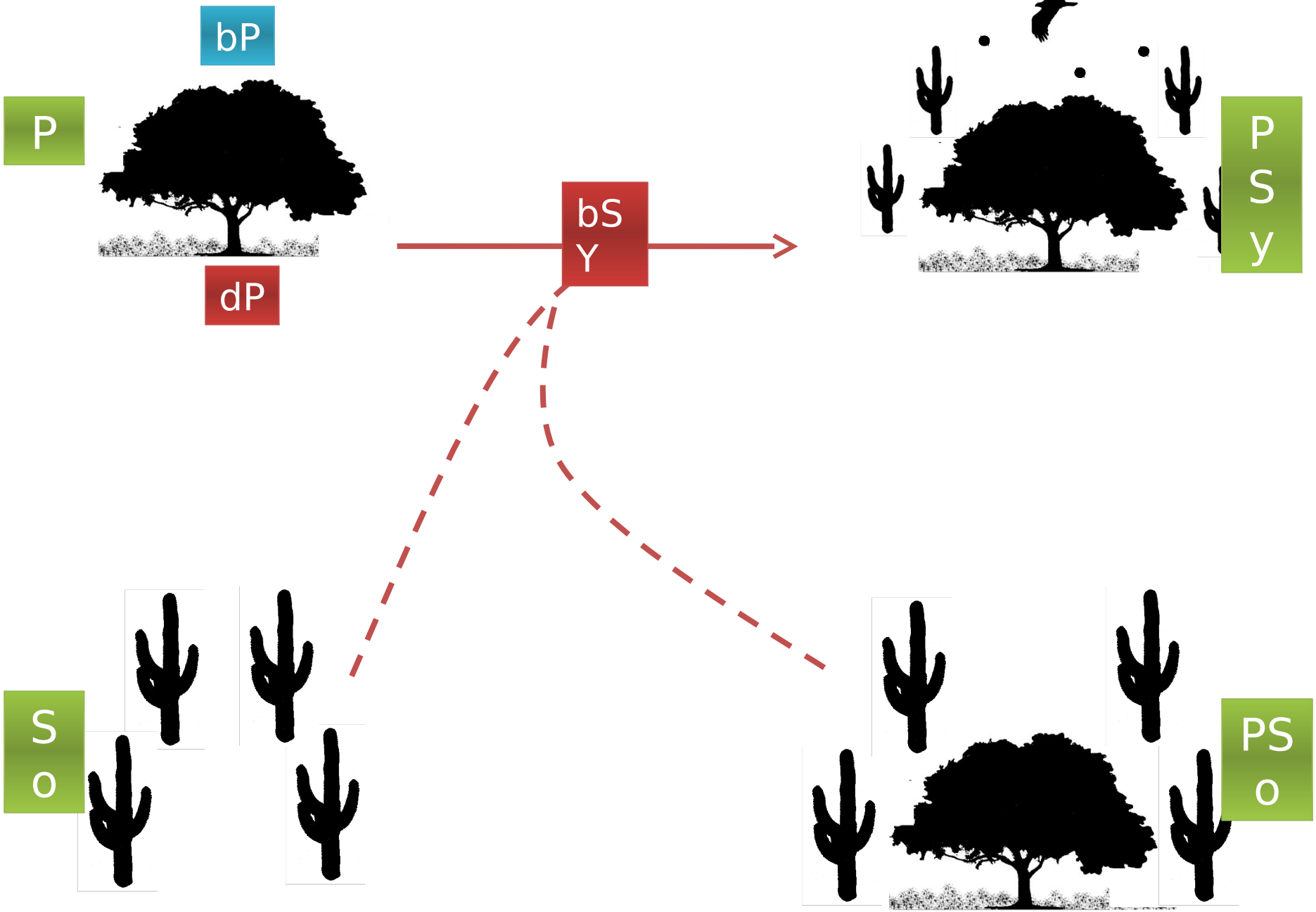
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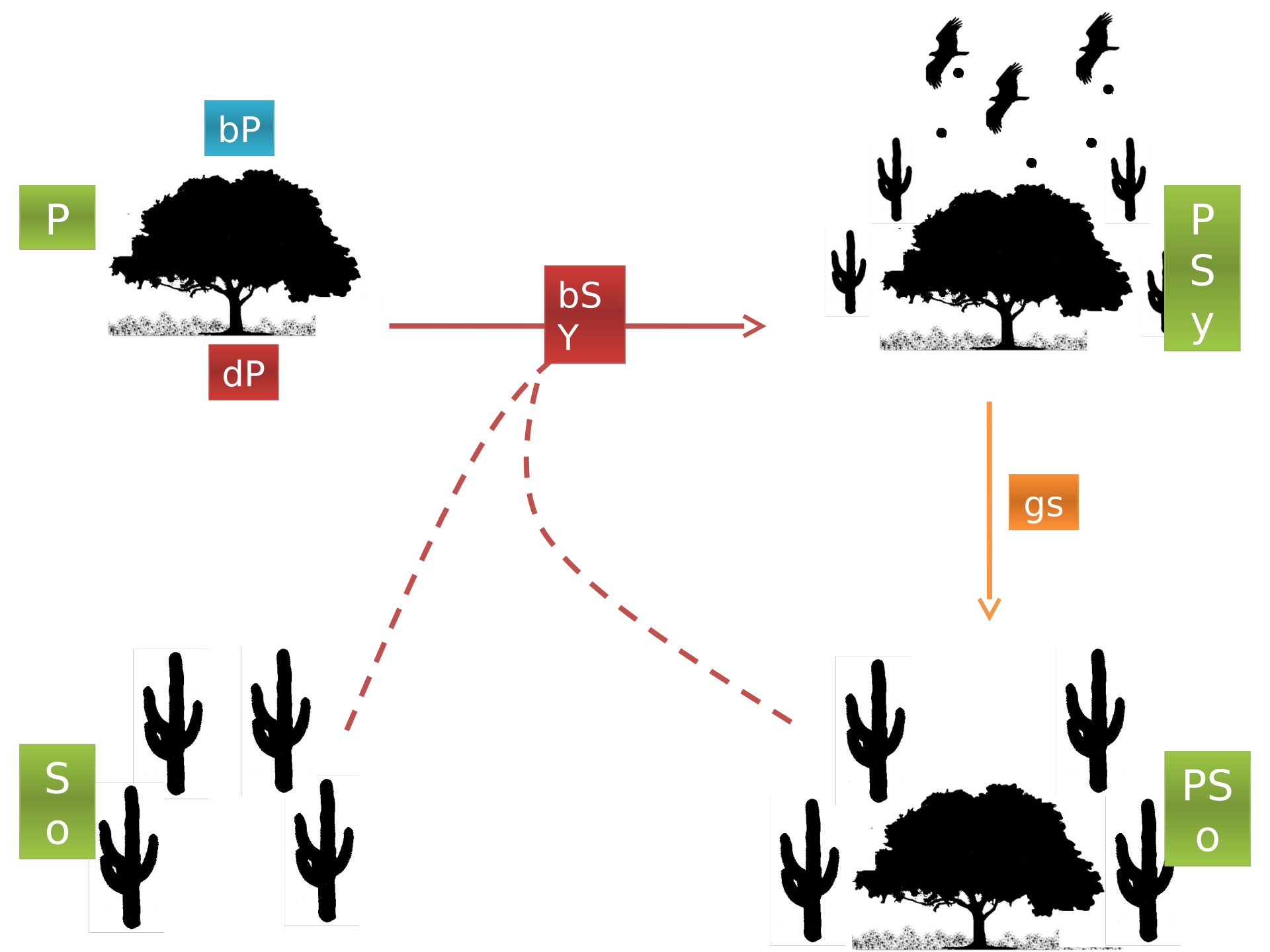
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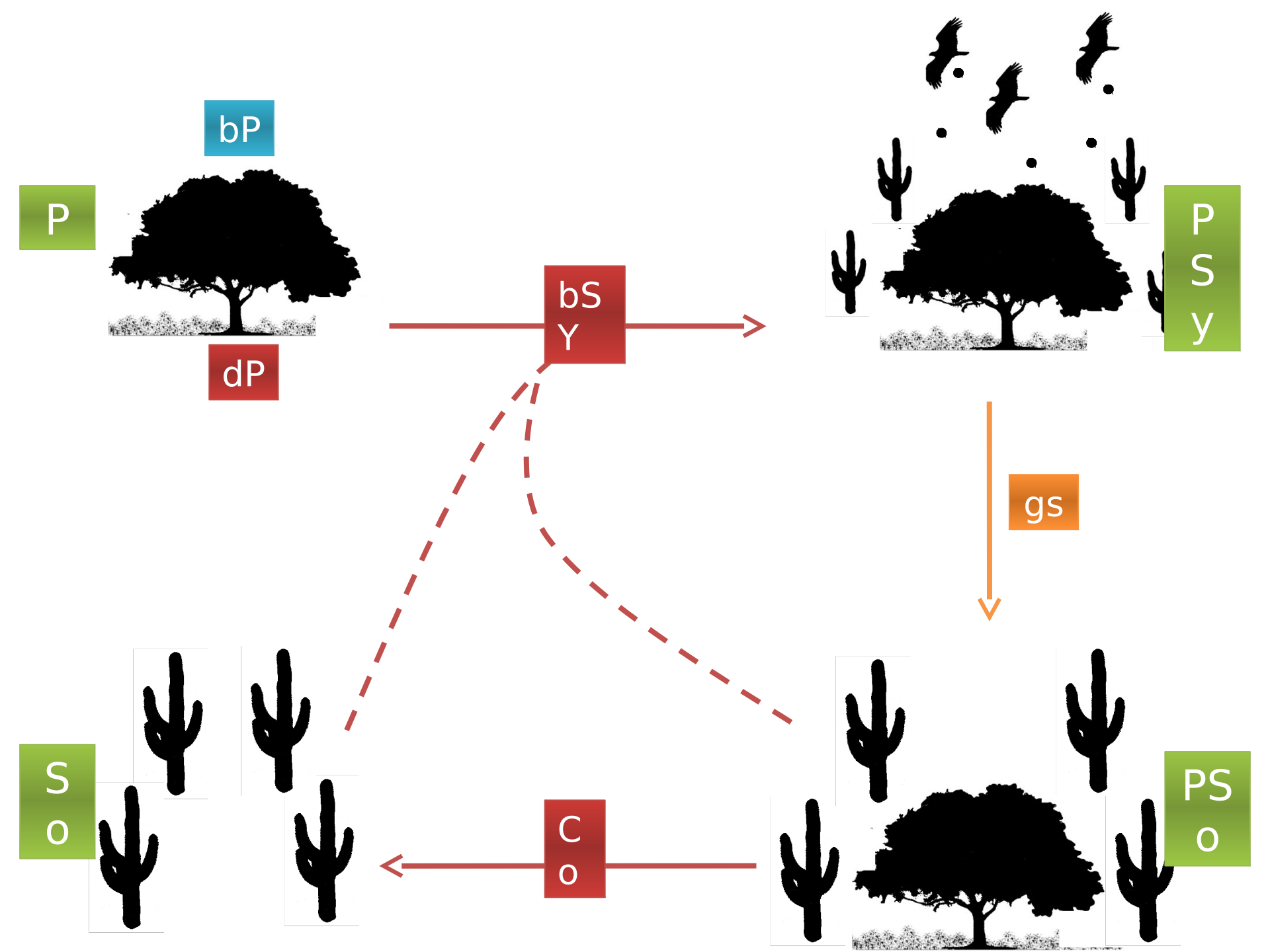
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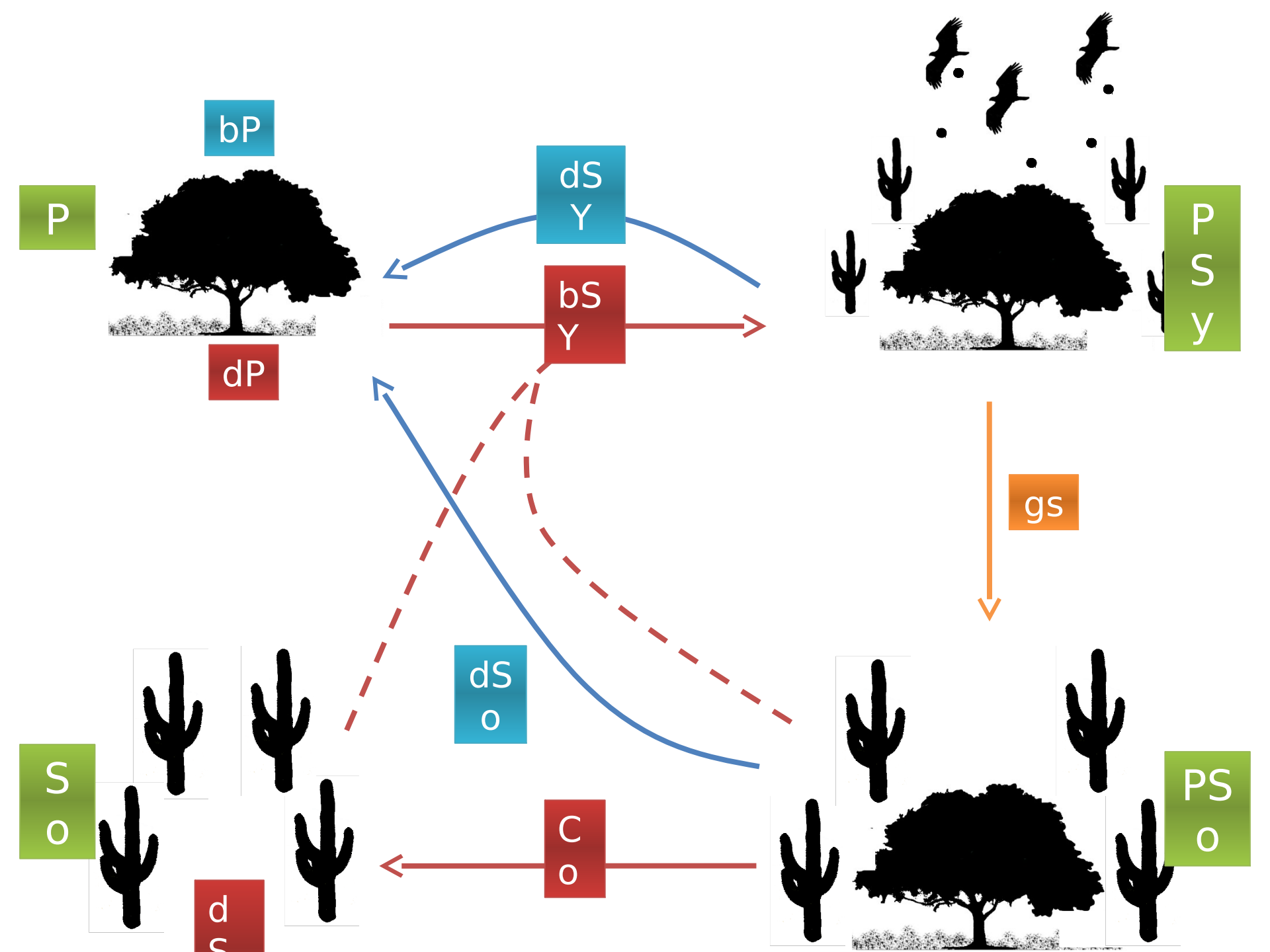
bP
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gs
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C
o
PS
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d
S

"Alien Cactus" Model

$$\frac{dP}{dt} = b_p P_T - d_p(1 + \frac{P_T}{K_P})P - b_{S_y}(P_{S_o} + S_o)P + d_{S_y}P_{S_y} + d_{S_o}P_{S_o}$$

PT : total number of Palo Verde trees (*PT* = *P* + *PSy* + *PSo*)

"Alien Cactus" Mode

$$\frac{dP_{S_y}}{dt} = b_{S_y}(P_{S_o} + S_o)P - g_S P_{S_y} - d_{S_y} P_{S_y} - d_p P_{S_y}$$

"Alien Cactus" Mode

$$\frac{dP_{S_o}}{dt} = g_S P_{S_y} - d_{S_o} P_{S_o} - d_p(1 + \frac{P_T}{K_P} + C_{S_o}) P_{S_o}$$

"Alien Cactus" Mode

$$\frac{S_o}{dt} = d_p(1 + \frac{P_T}{K_P} + C_{S_o})P_{S_o} - d_{S_o}S_o$$

"Alien Cactus" Mode

$$\frac{dP}{dt} = b_p P_T - d_p(1 + \frac{P_T}{K_P})P - b_{S_y}(P_{S_o} + S_o)P + d_{S_y}P_{S_y} + d_{S_o}P_{S_o}$$

$$\frac{dP_{S_y}}{dt} = b_{S_y}(P_{S_o} + S_o)P - g_S P_{S_y} - d_{S_y}P_{S_y} - d_p P_{S_y}$$

$$\frac{dP_{S_o}}{dt} = g_S P_{S_y} - d_{S_o}P_{S_o} - d_p(1 + \frac{P_T}{K_P} + C_{S_o})P_{S_o}$$

$$\frac{S_o}{dt} = d_p(1 + \frac{P_T}{K_P} + C_{S_o})P_{S_o} - d_{S_o}S_o$$

Possible Outcomes

- **Endemy/Coexistence: Both species survives**
- **Recovery: Cacti extinction**
- **Extinction: Both species extinct**

Exploring the model

- Differential equations solved by numerical integration.

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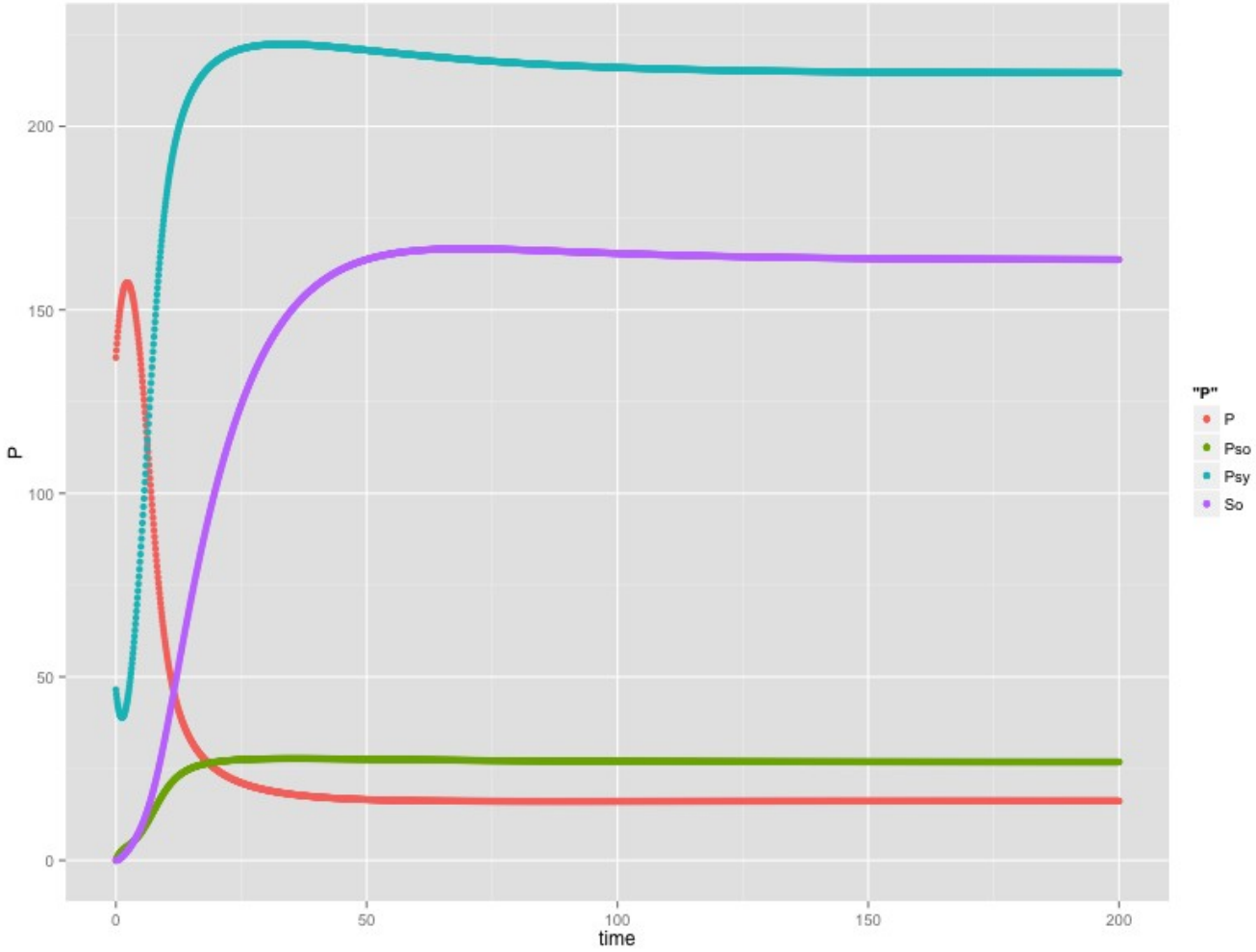
- Initial conditions:
    - P: high population
    - Psy: low population
    - Pso: absent
    - So: absent

Exploring the model

- Differential equations solved by numerical integration.
- Initial conditions:
    - P: high population
    - Psy: low population
    - Pso: absent
    - So: absent
- Parameter space explored with the Latin Hypercube

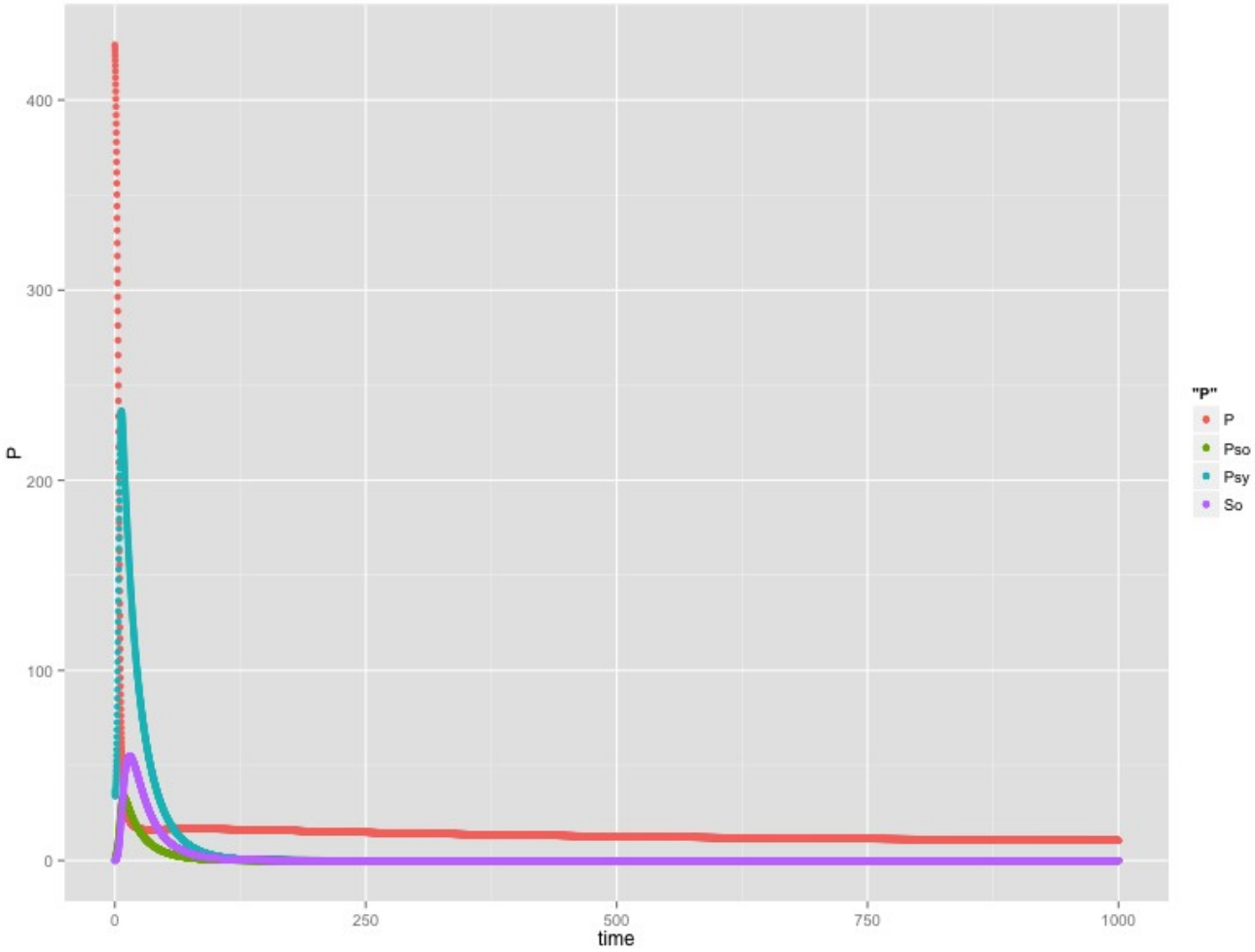
Model Outcomes

Endemy/Coexistence: Both species su



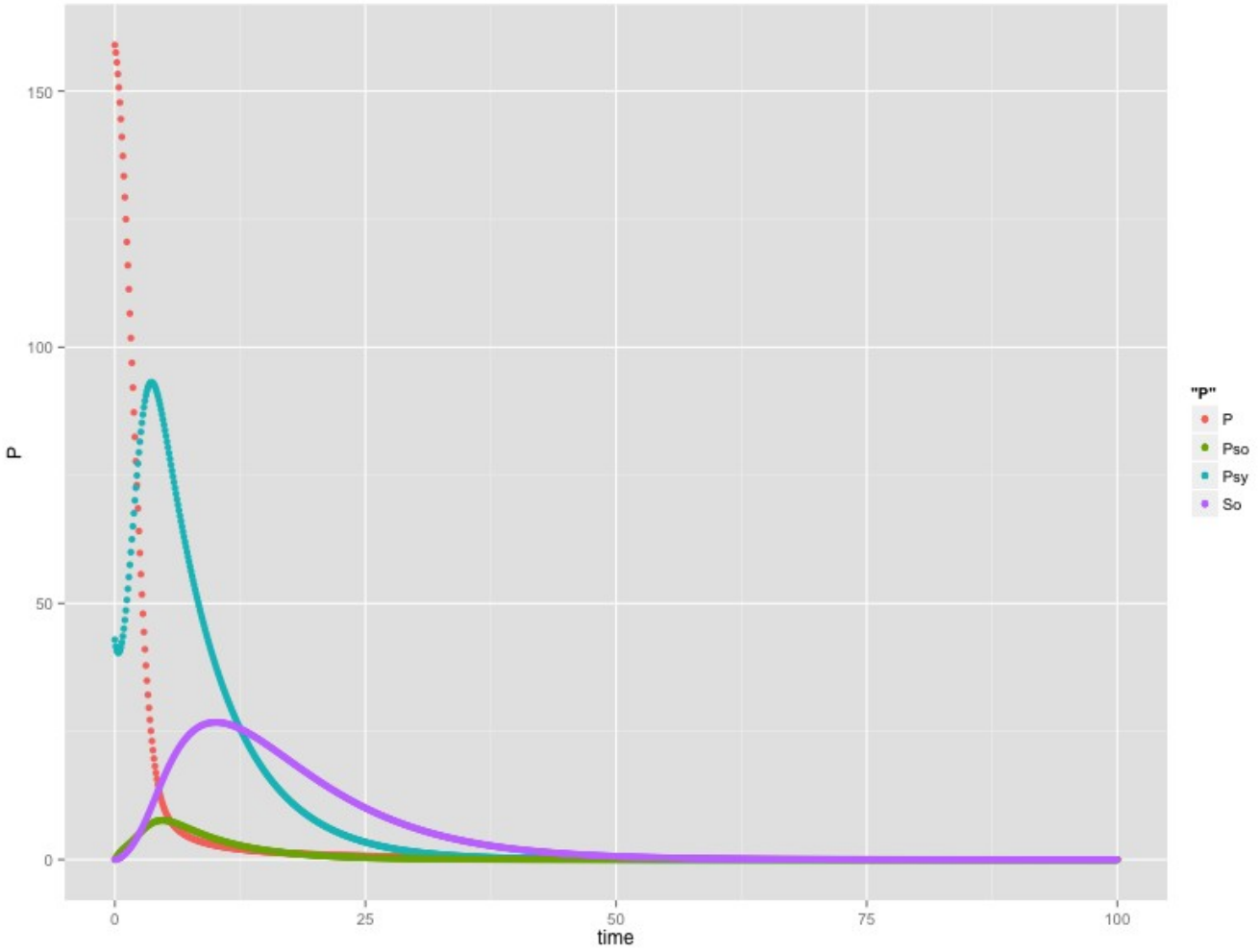
Model Outcomes

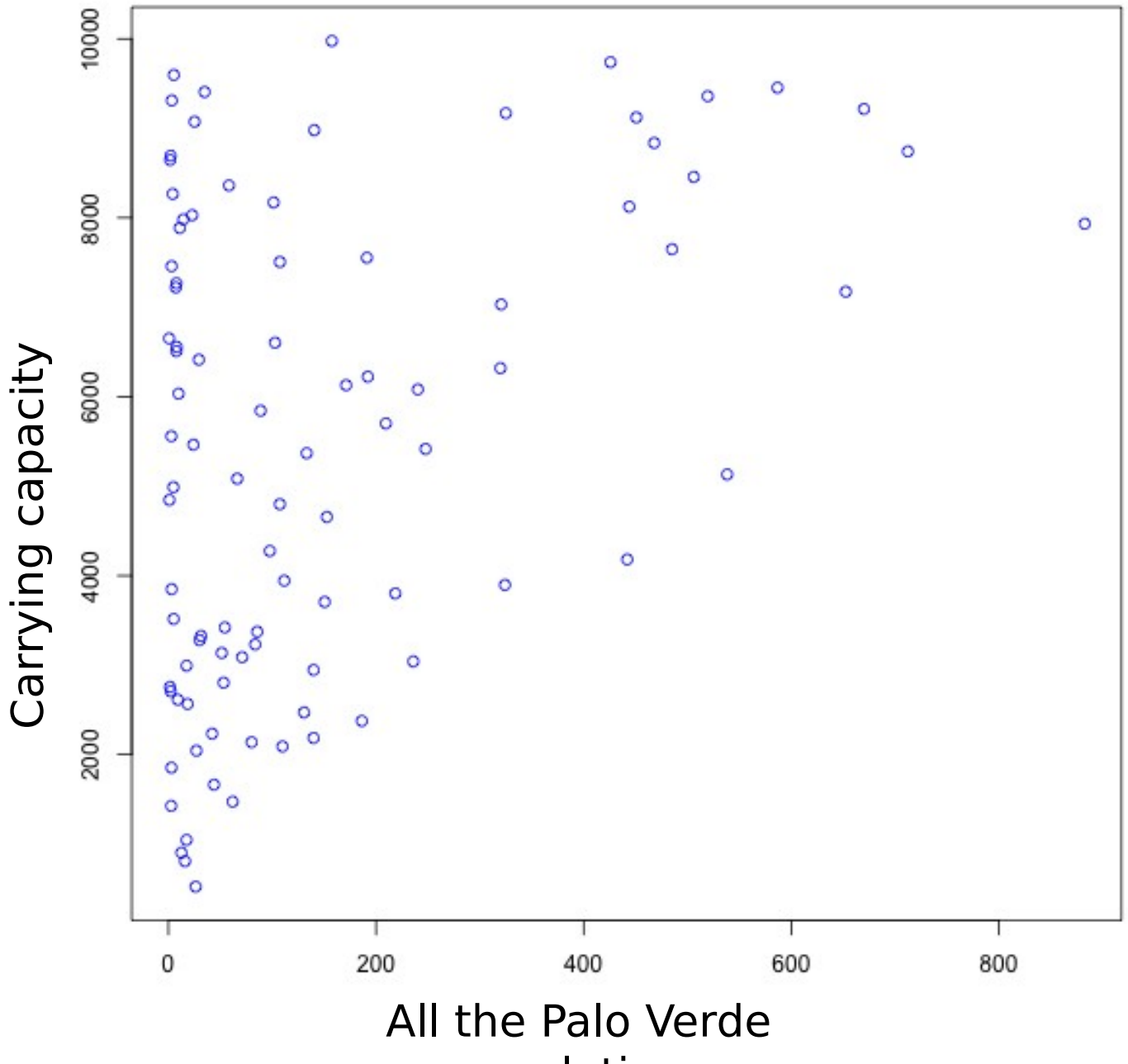
Recovery: Cacti



Model Outcomes

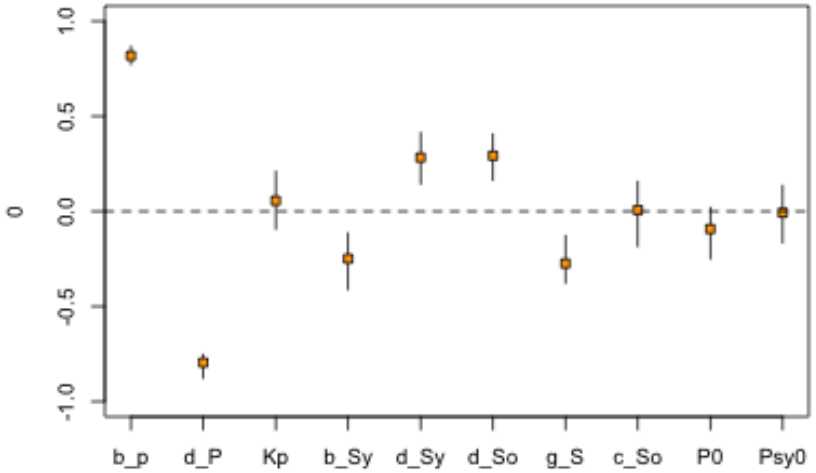
Extinction: Both



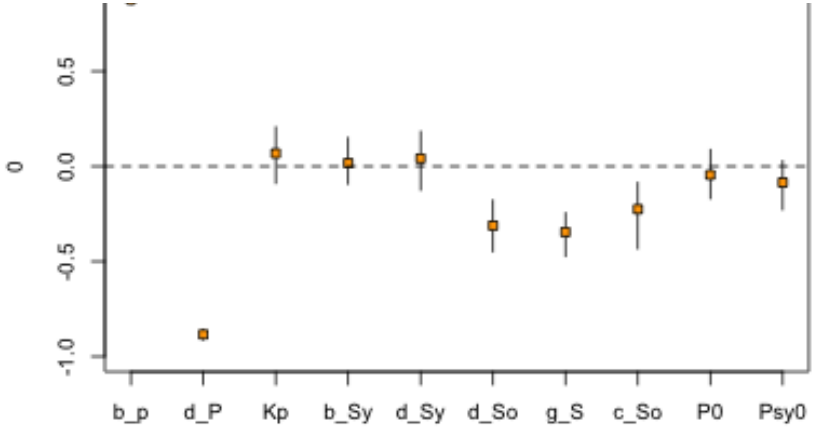

Carrying capacity
10000
8000
6000
4000
2000
0
200
400
600
800
All the Palo Verde

Partial Rank Correlation Coefficients

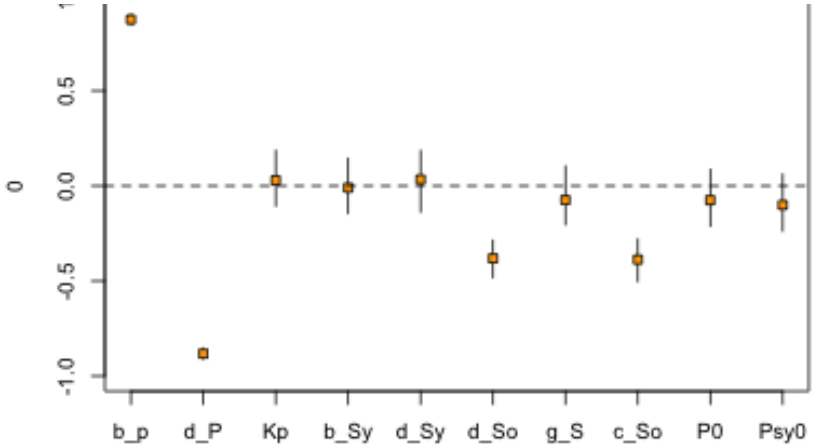
All the Palo Verde populations



Palo Verde infected by young Saguaros

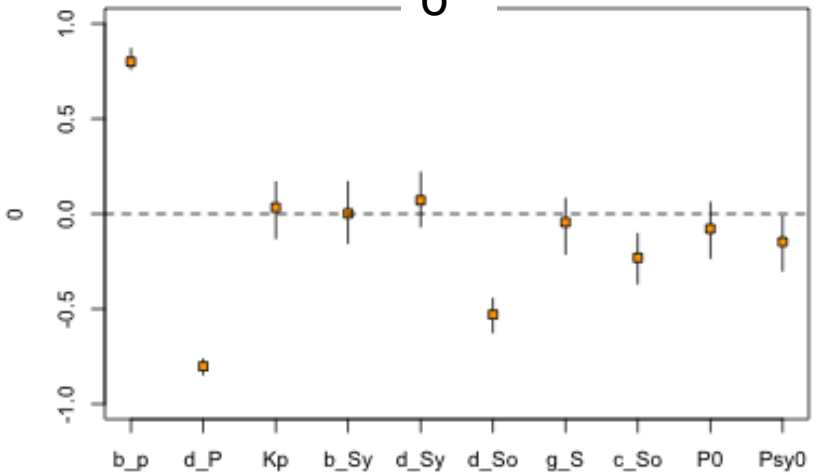


Palo Verde infected by adult Saguaros



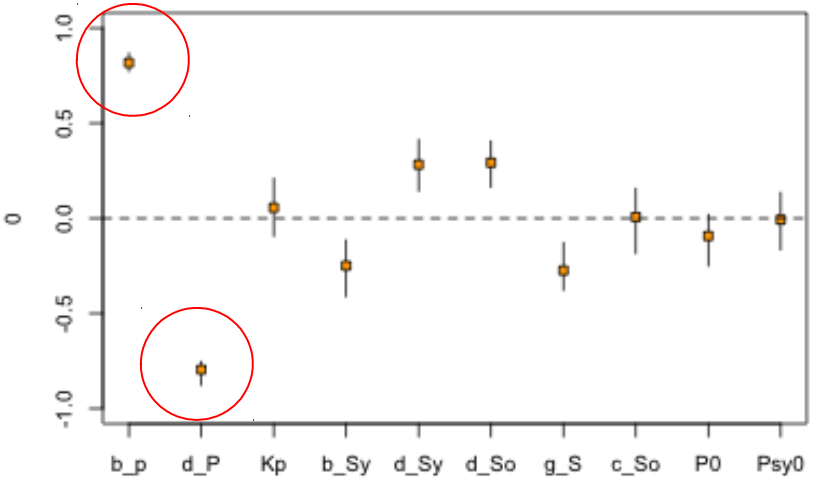
Adult Saguaros

o



Partial Rank Correlation Coefficients

All the Palo Verde populations



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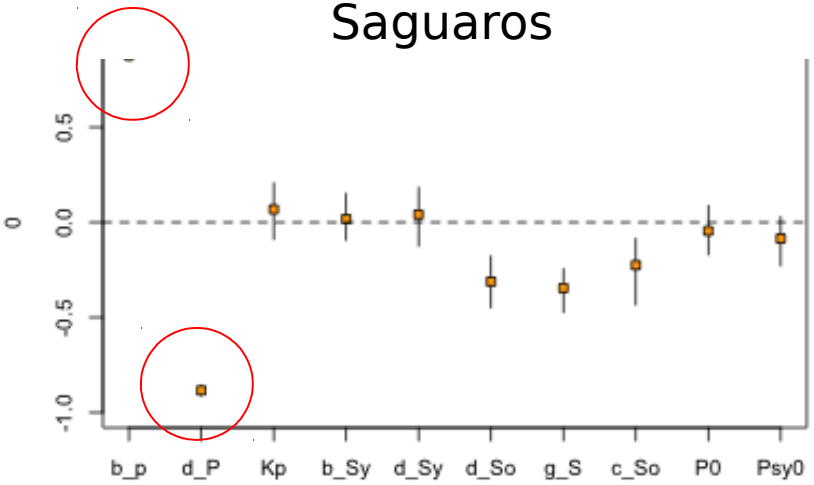
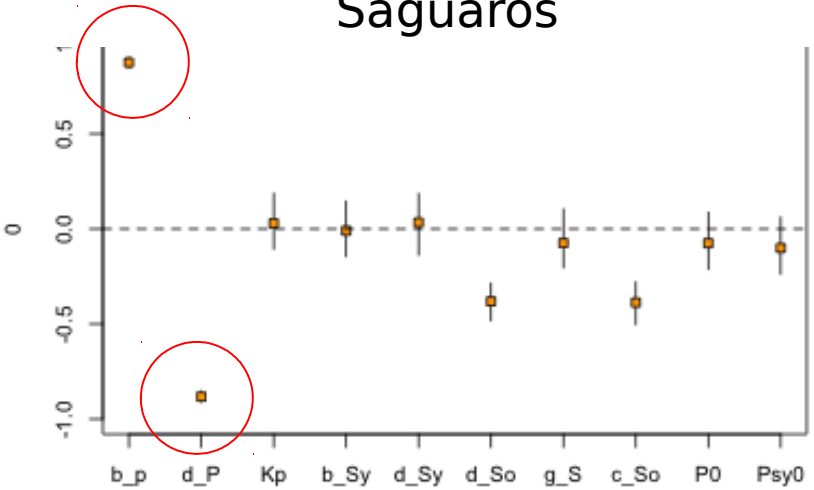


Large correlation coefficients for bp and dp

Palo Verde infected by adult Saguaros



Adult Saguaros

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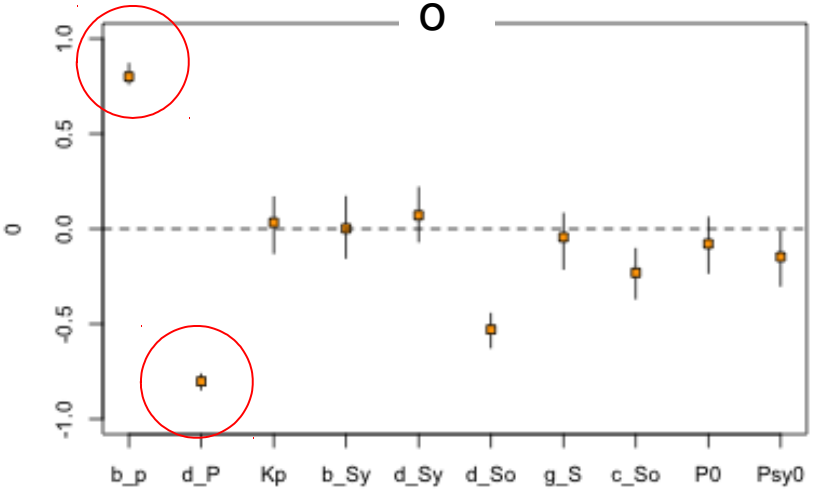
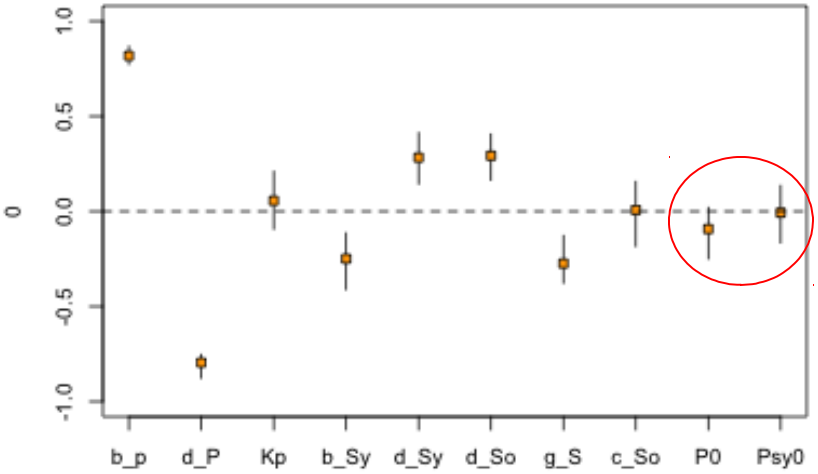


Partial Rank Correlation Coefficients

All the Palo Verde populations



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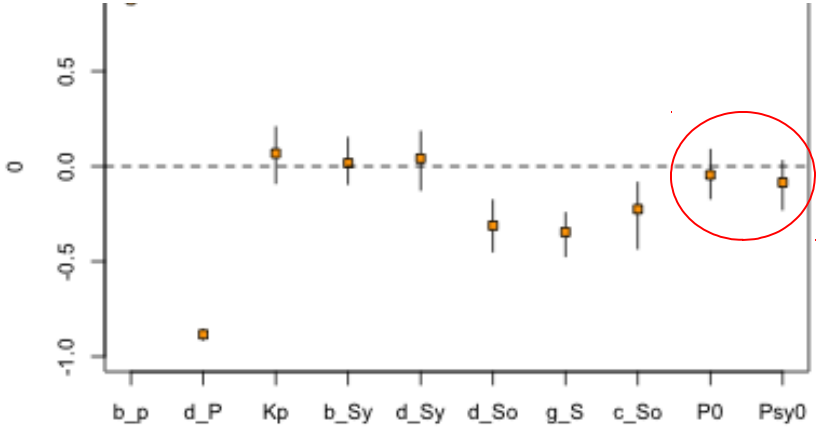
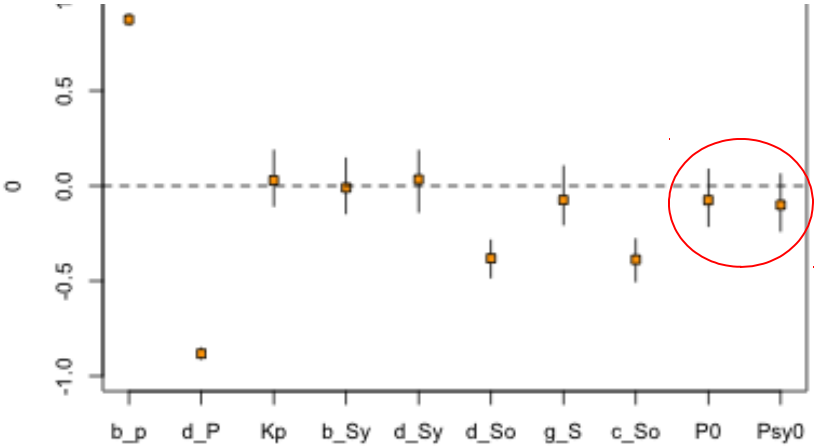
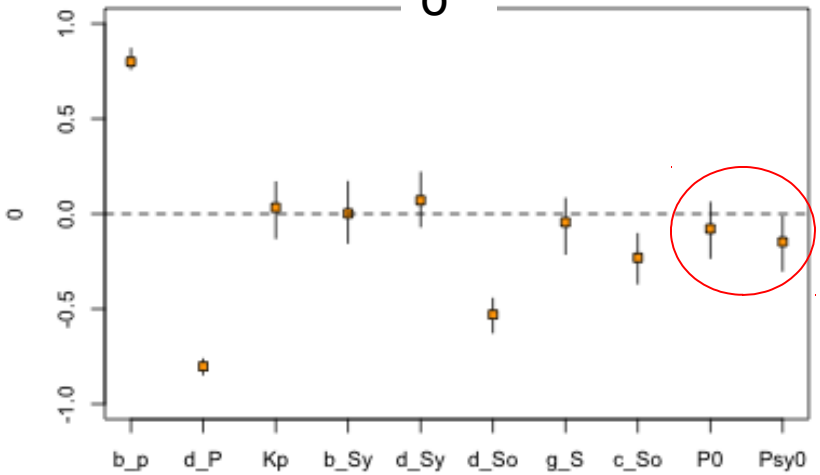


No effect of the initial conditions

Palo Verde infected by adult Saguaros

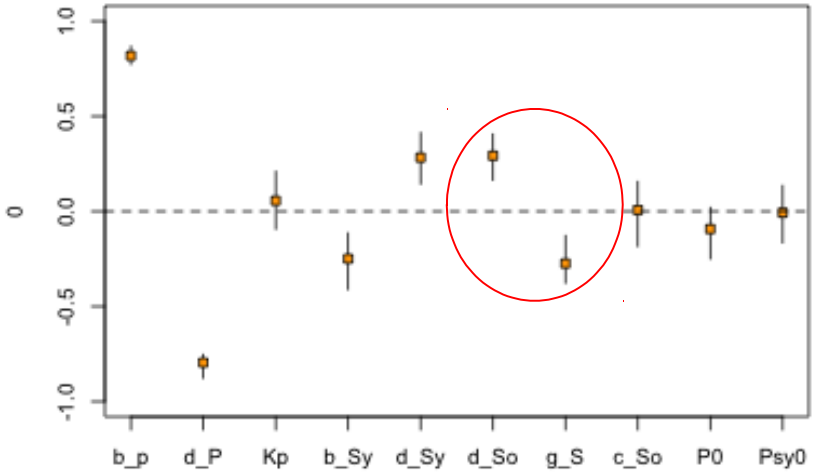


Adult Saguaros



Partial Rank Correlation Coefficients

All the Palo Verde populations



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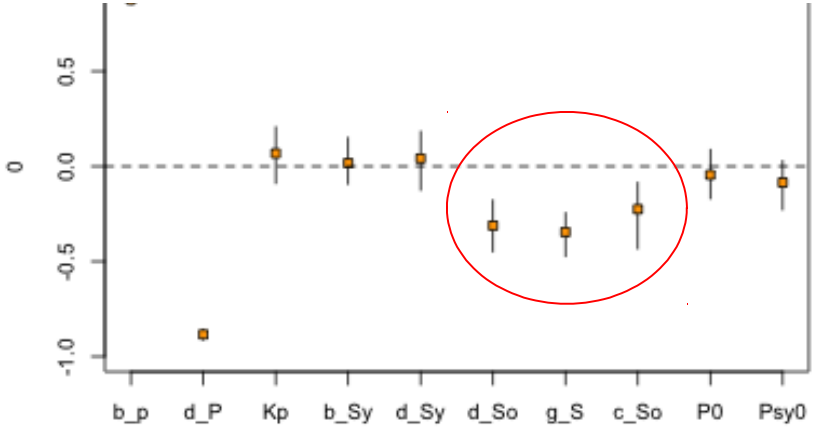
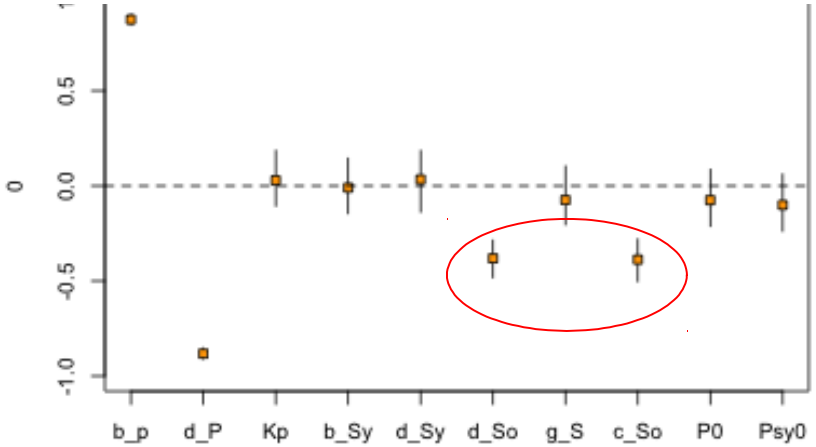
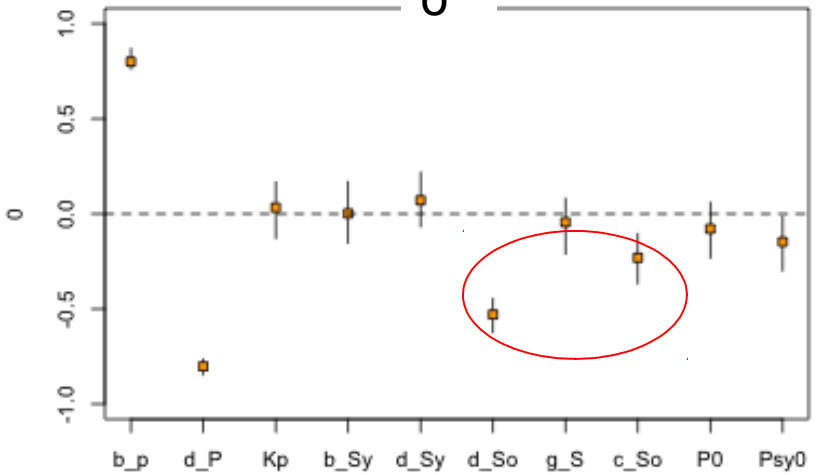


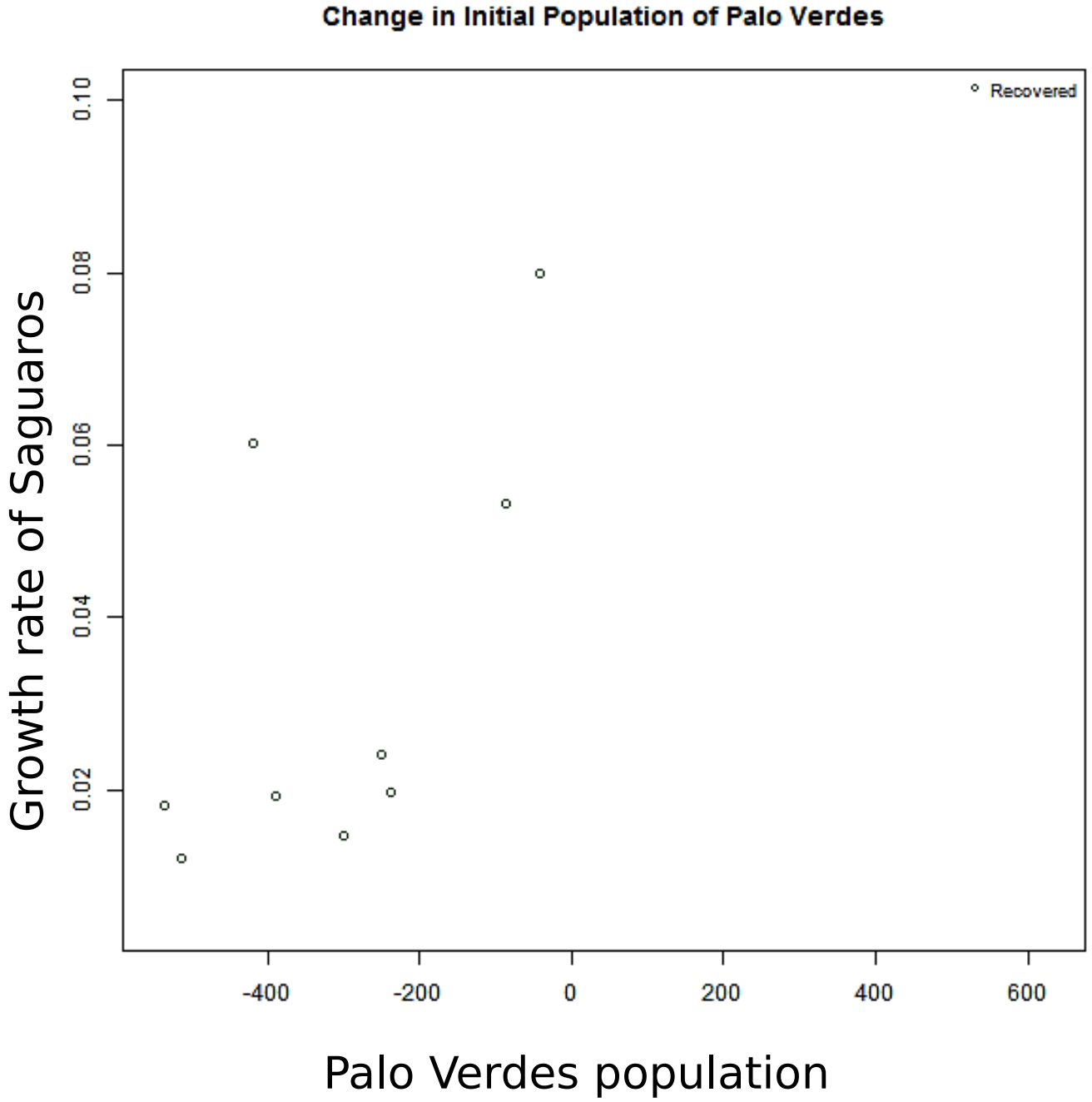
Significant effects of dSo, gS and cSo

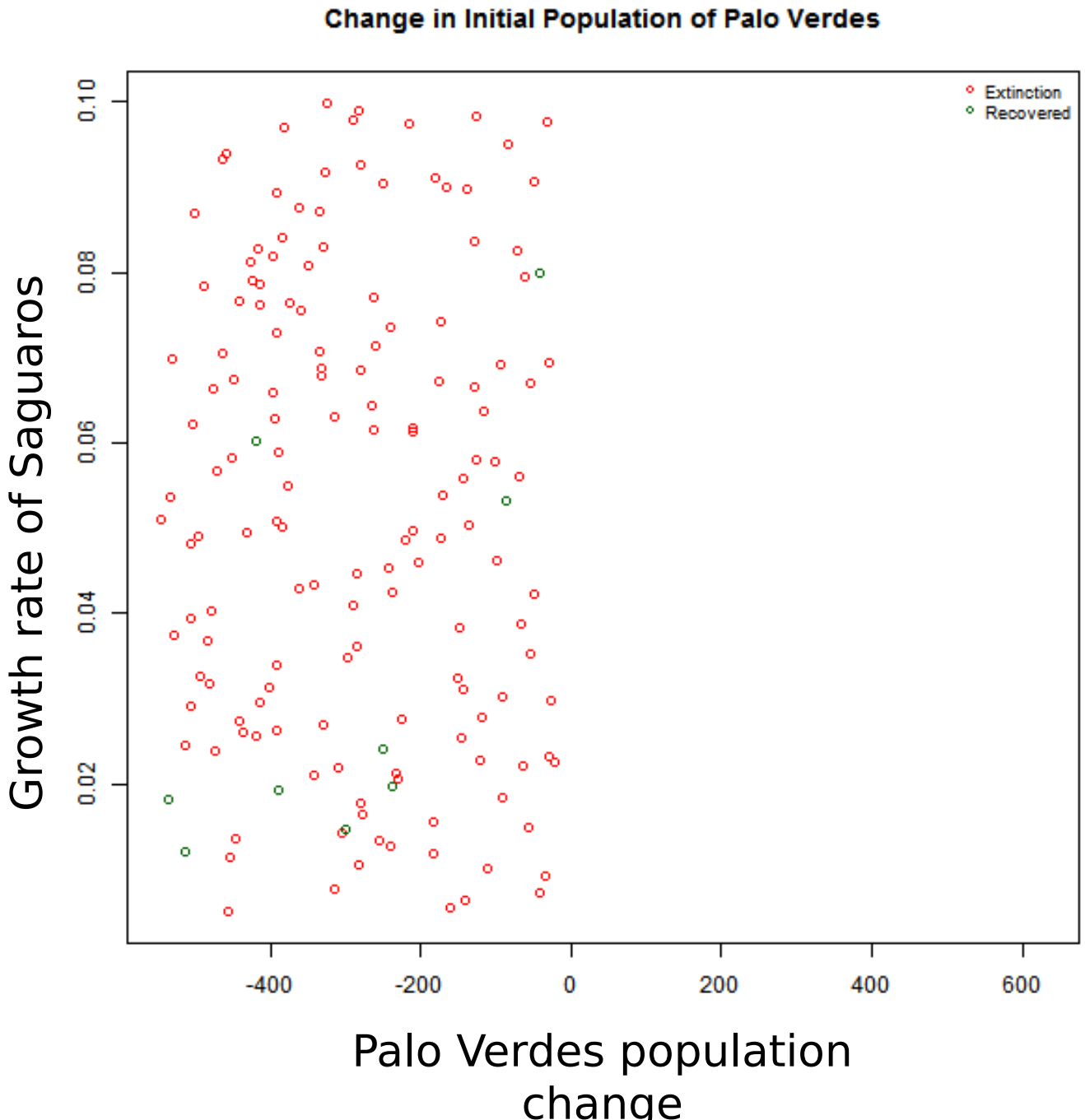
Palo Verde infected by adult Saguaros



Adult Saguaros




Change in Initial Population of Palo Verdes
Recovered
Growth rate of Saguaros
0.02
0.04
0.06
0.08
0.10
-400
-200
0
200
400
600
Palo Verdes population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0.10
-400
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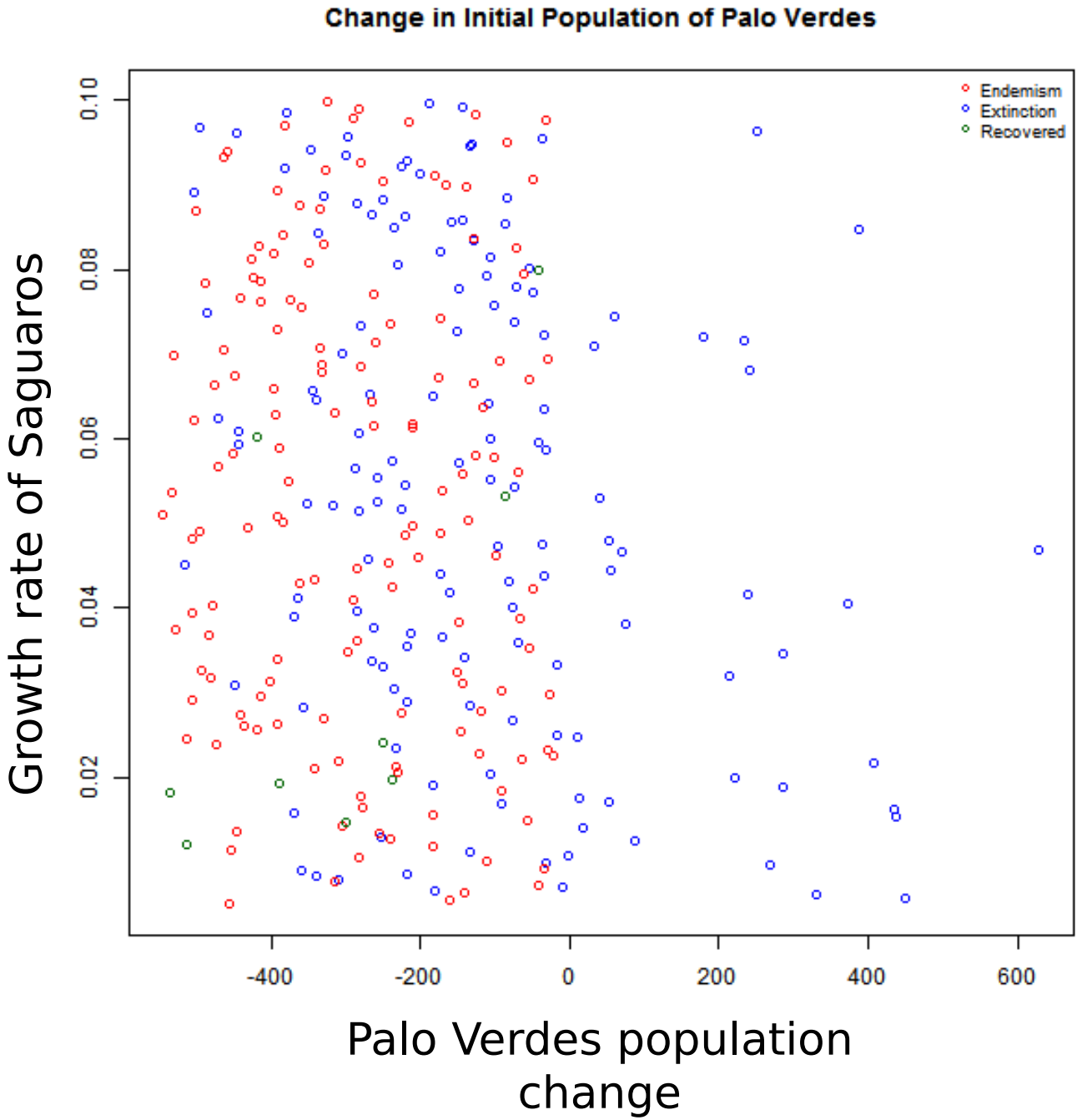
0
200
400
600
Palo Verdes population change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Extinction
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200
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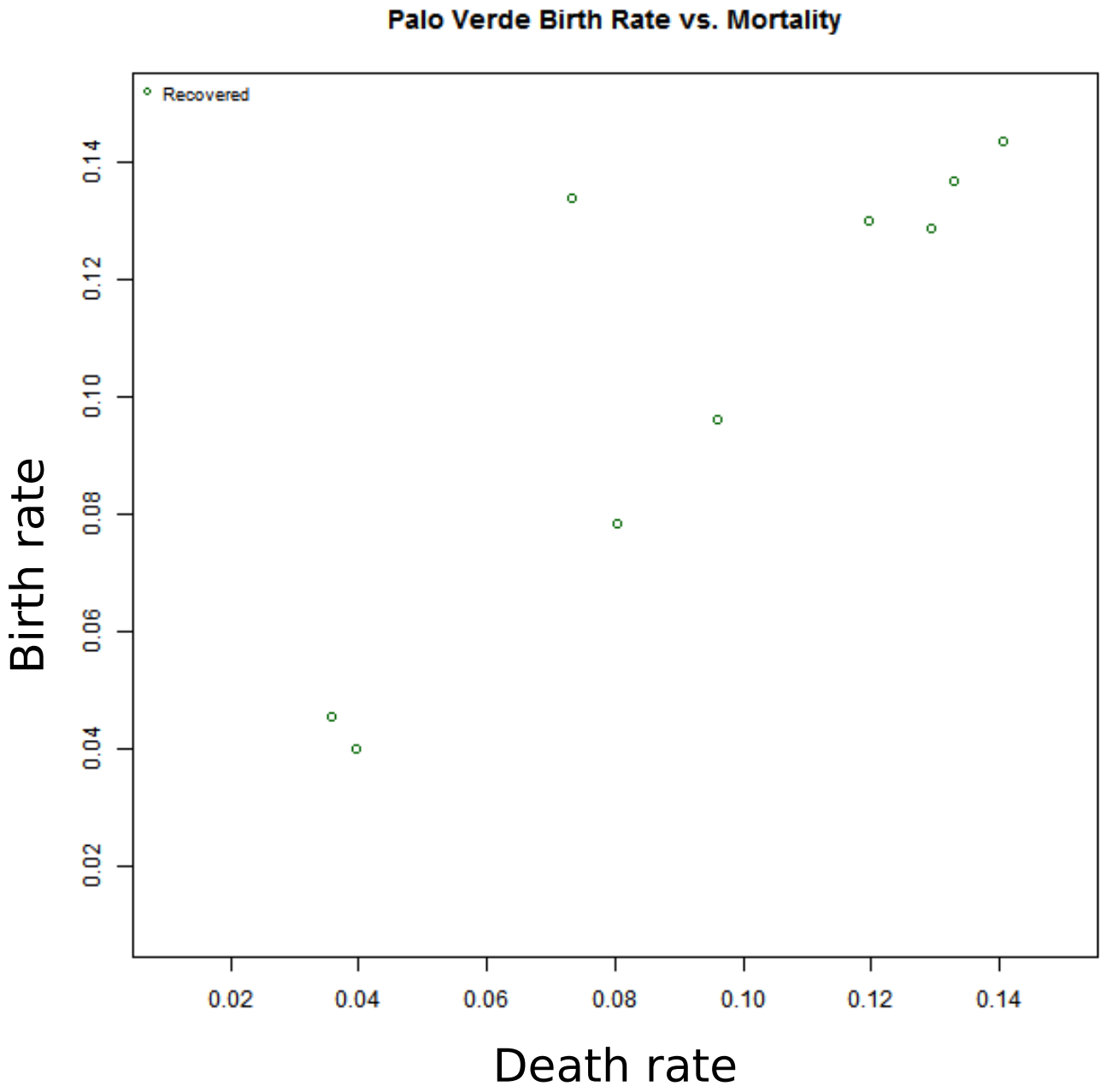
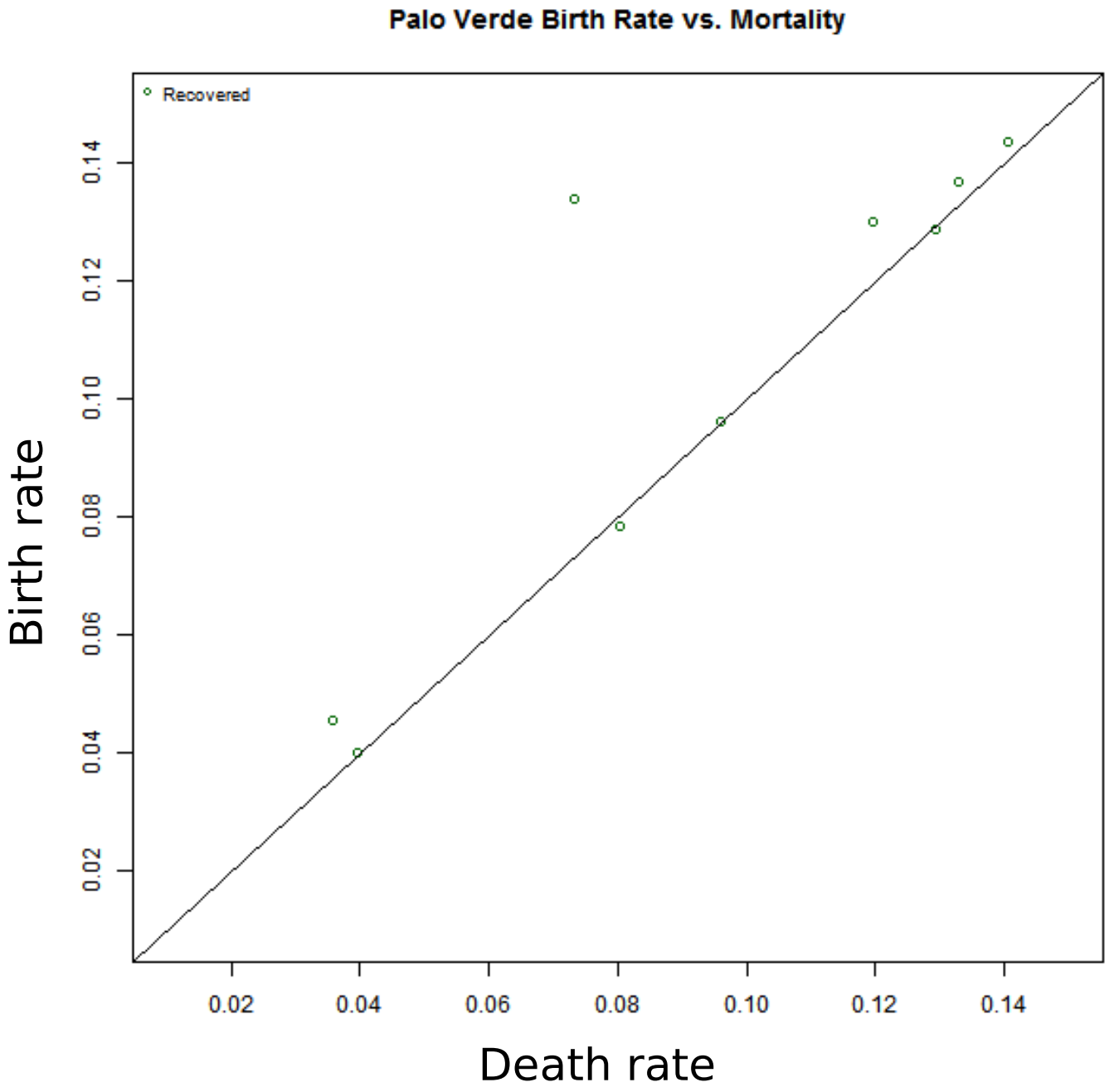
600
Palo Verdes population change


Palo Verde Birth Rate vs. Mortality
Recovered
Birth rate
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Death rate
0.02
0.04
0.06
0.08
0.10
0.12
0.14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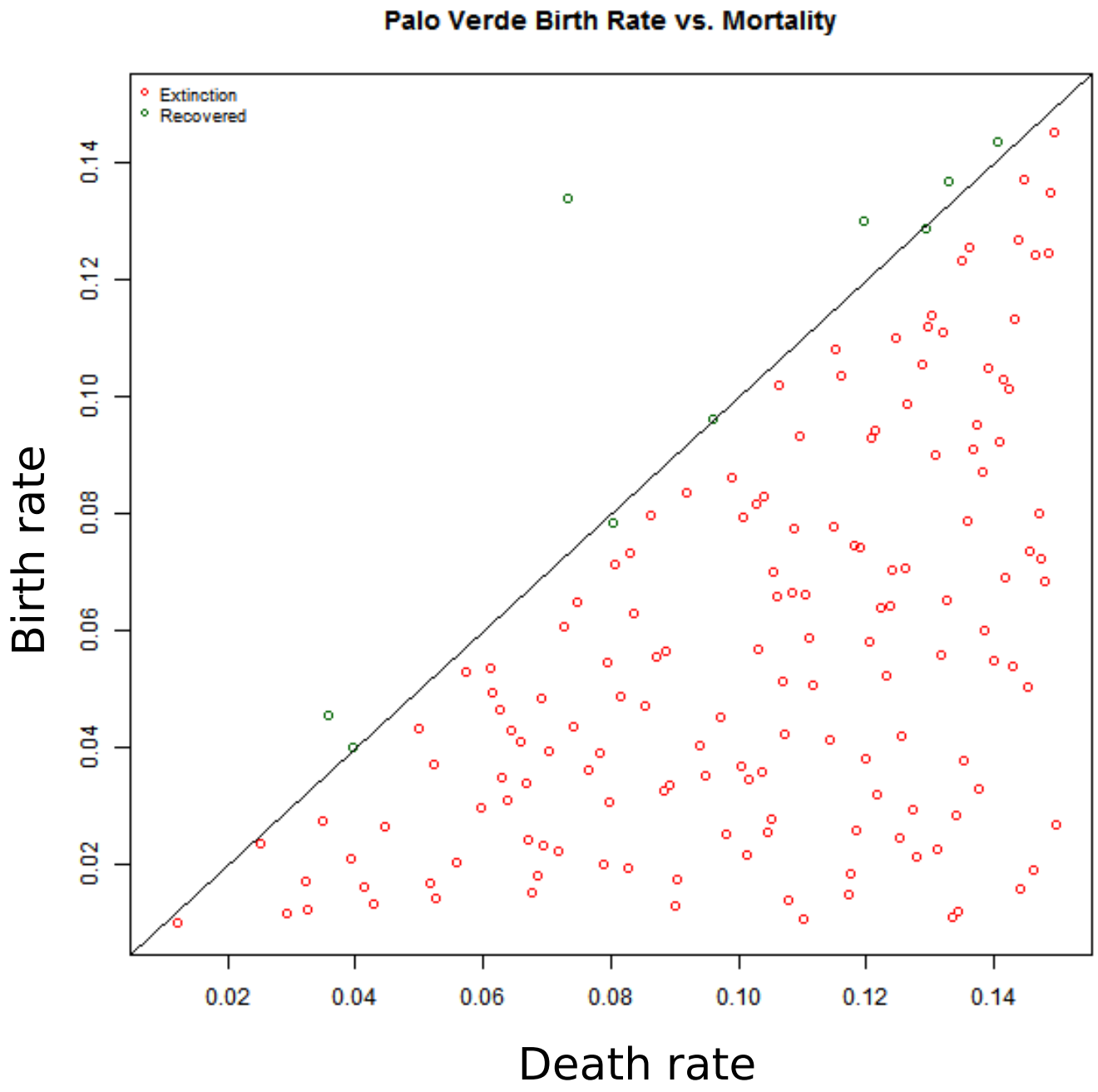
0.02
0.04
0.06
0.08
0.10
0.12
0.14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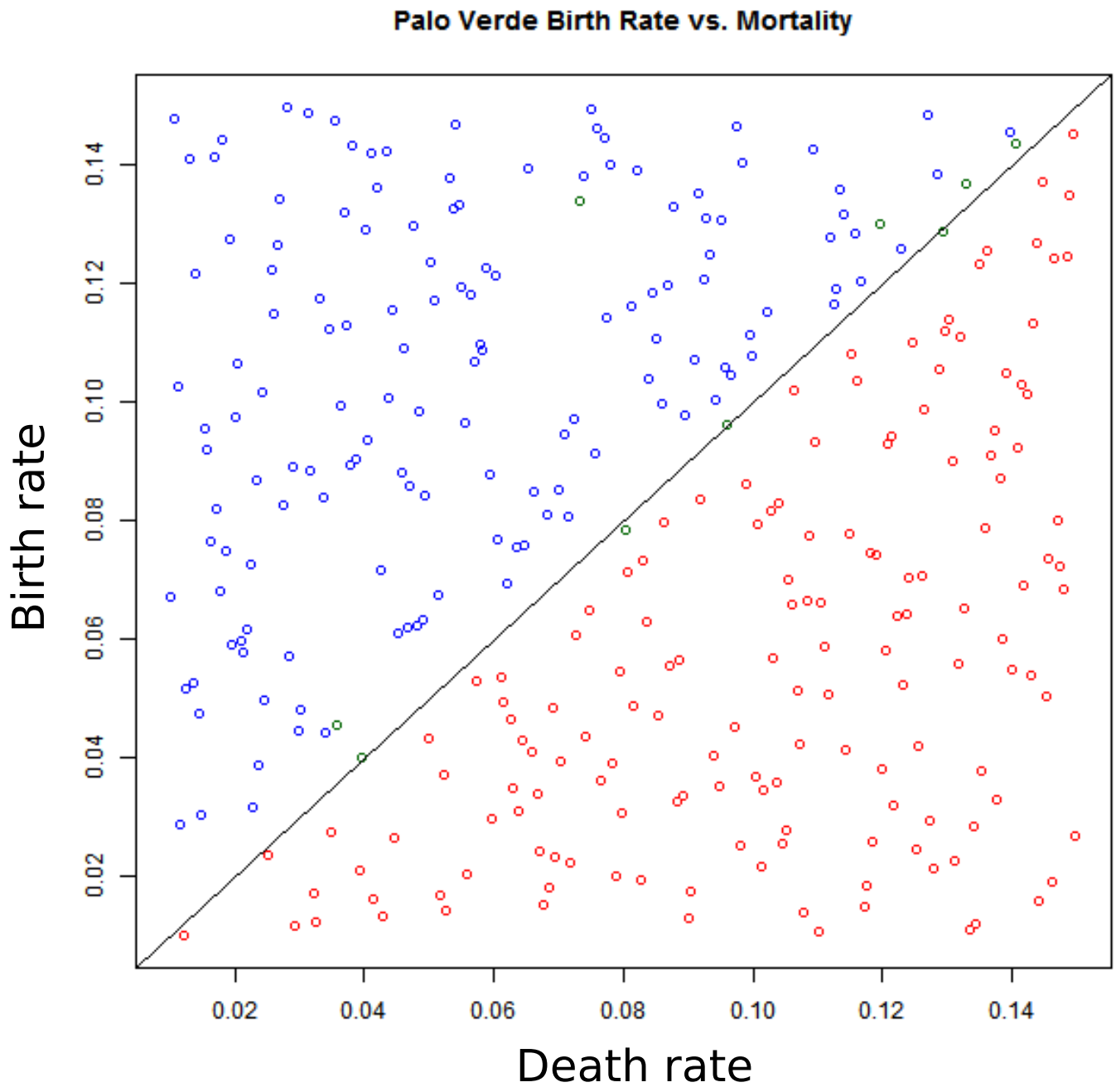
0.12
0.14


Palo Verde Birth Rate vs. Mortality
Birth rate
Death rate
0.02
0.04
0.06
0.08
0.10
0.12
0.14

Conclusions

- **Endemy/Coexistence: Both species survives**

bP > dP

- **Recovery: Cacti extinction**

bP = dP

- **Extinction: Both species extinct**

bP < dP

Conclusions

Competition rate (cSo), death rate of old cacti (dSo) and maturation rate of cacti (gS) seem to play an important role in the dynamics

Next steps:

- Explore other parameters while controlling the effects of bp and dp
- Explicitly include abiotic stress (water availability, temperature conditions, etc)