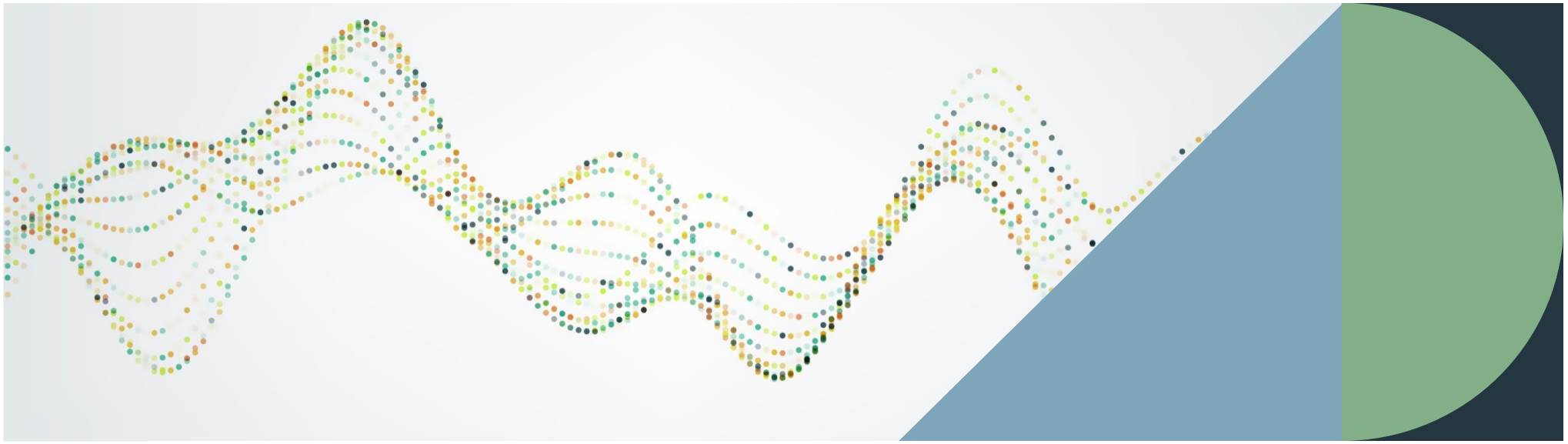


Species coexistence in an ever-changing world

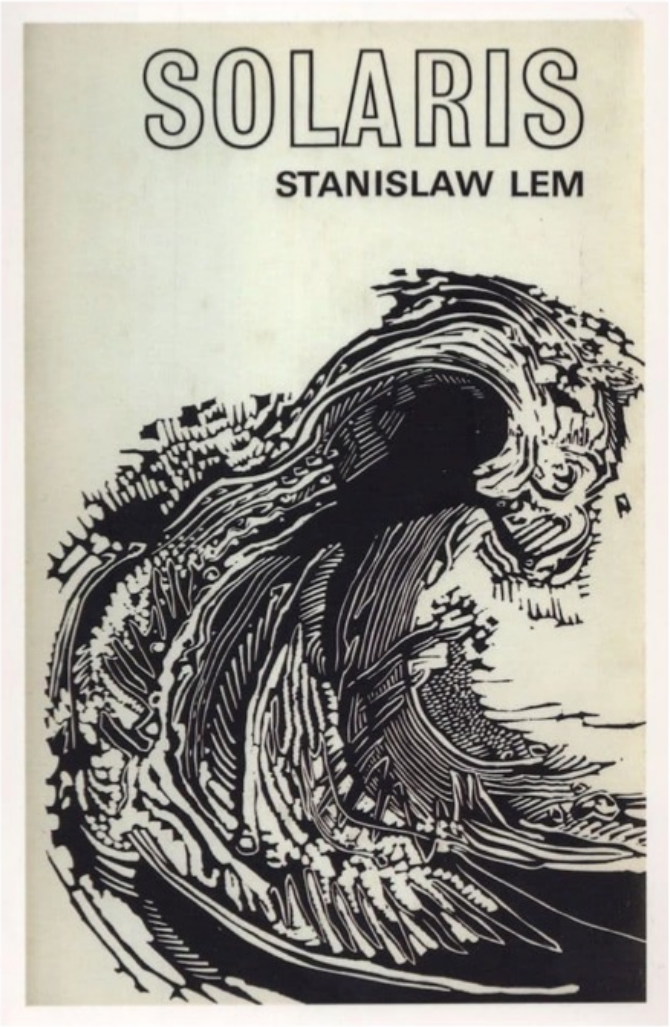
Oscar Godoy

EBD-CSIC

Estación Biológica Doñana CSIC

Why nature is biodiverse?





How can we describe changes in nature?



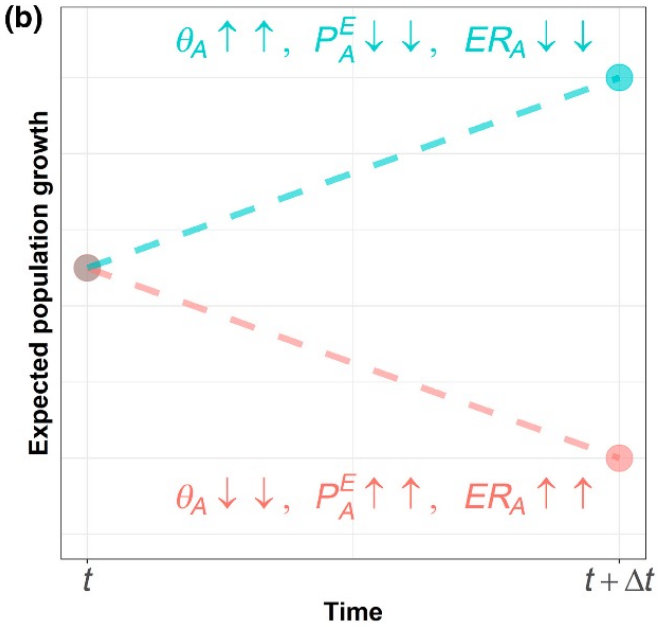
Mechanistic understanding

TRADE-OFF

Predictive ability



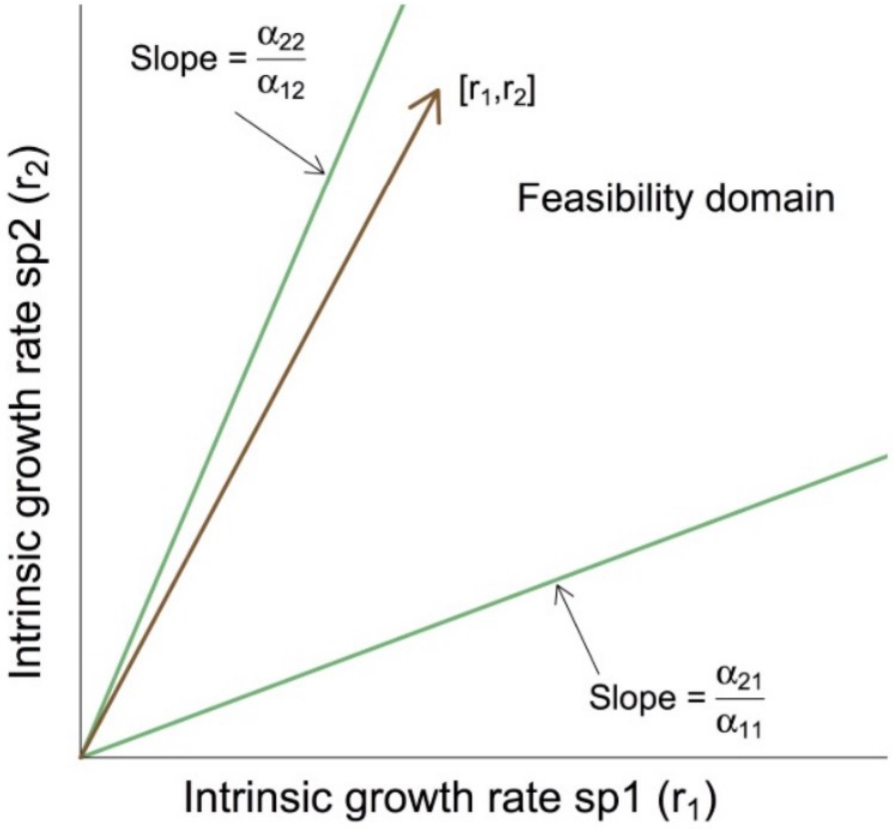
$$\frac{dN_i}{dt} = N_i\left(r_i + \sum_{j=1}^{S} \alpha_{ij} N_j\right)$$



Mechanistic understanding

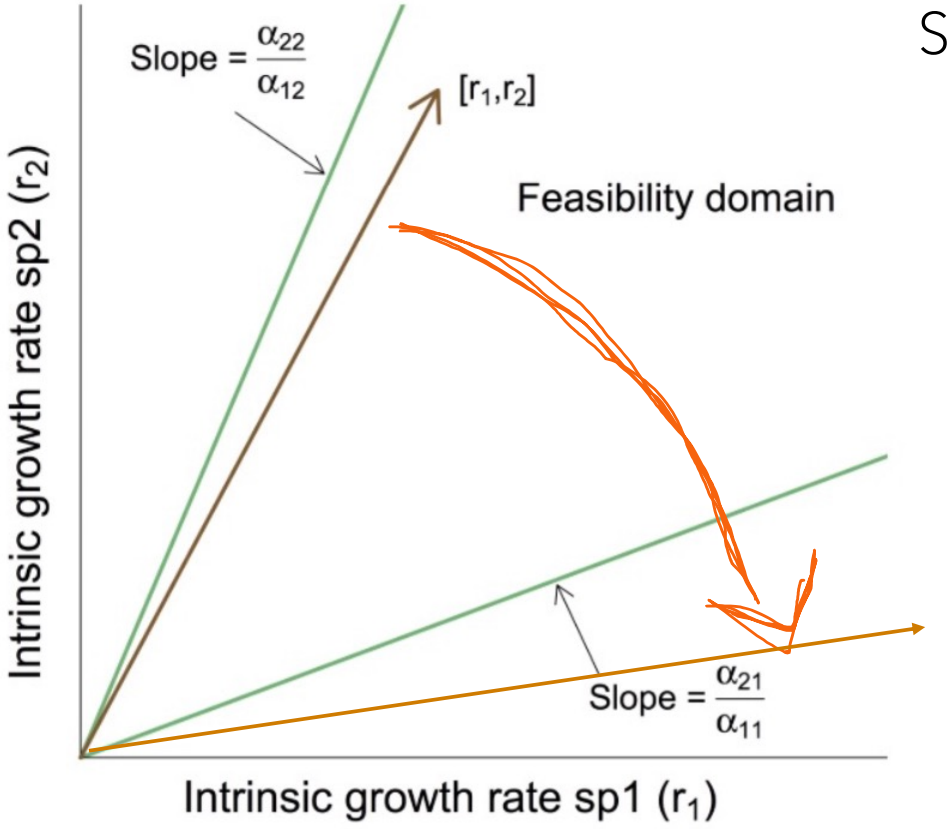
Predicting abilities

Structural Stability, 2 species



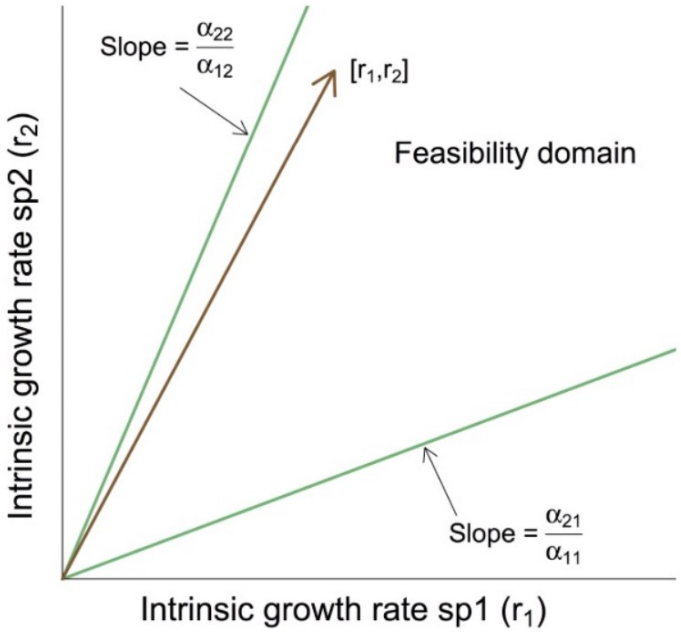
Coexistence scenario

Structural Stability, 2 species

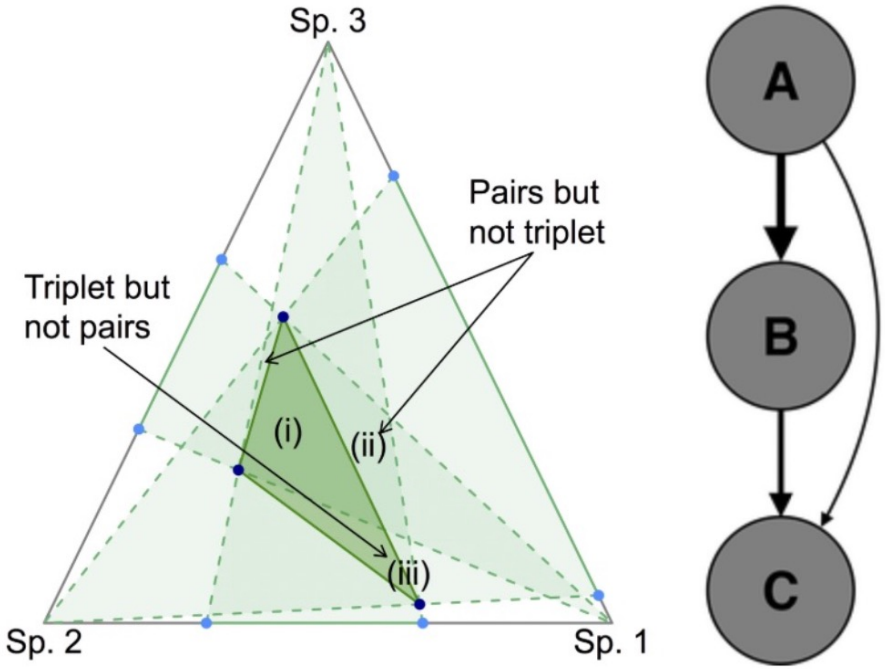


Species 2 excluded

Structural Stability, 3 species

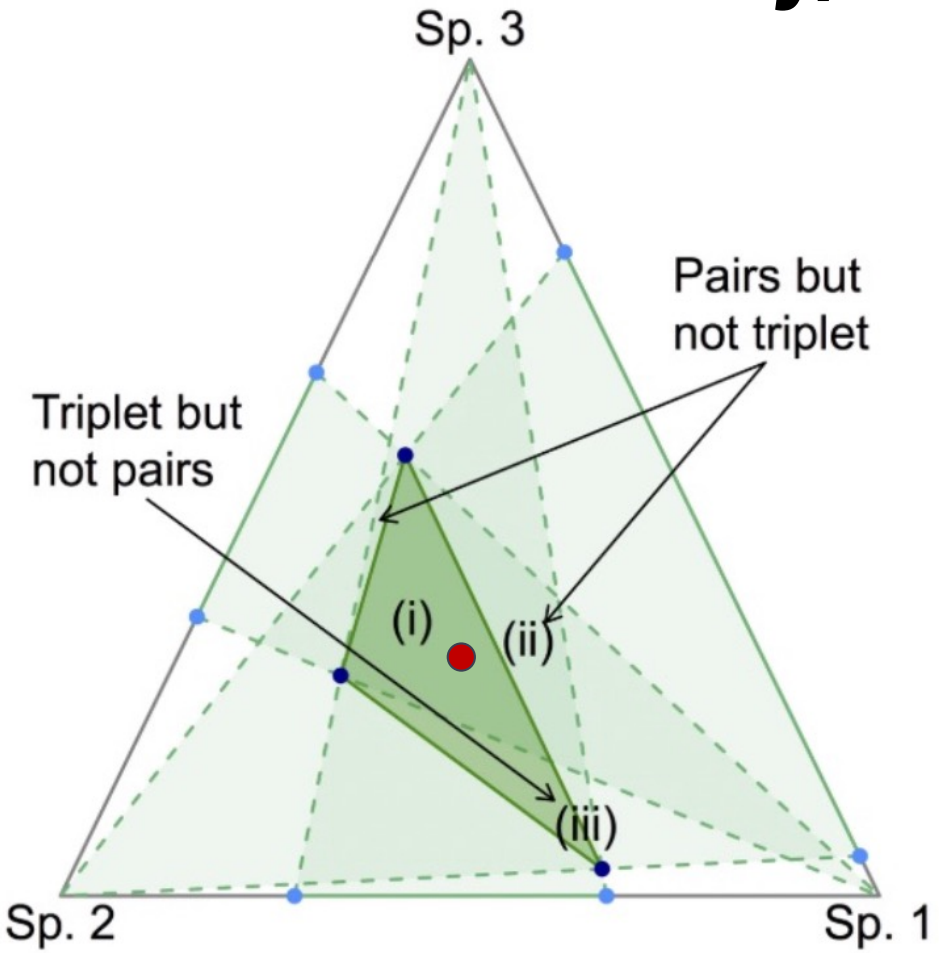


Two species



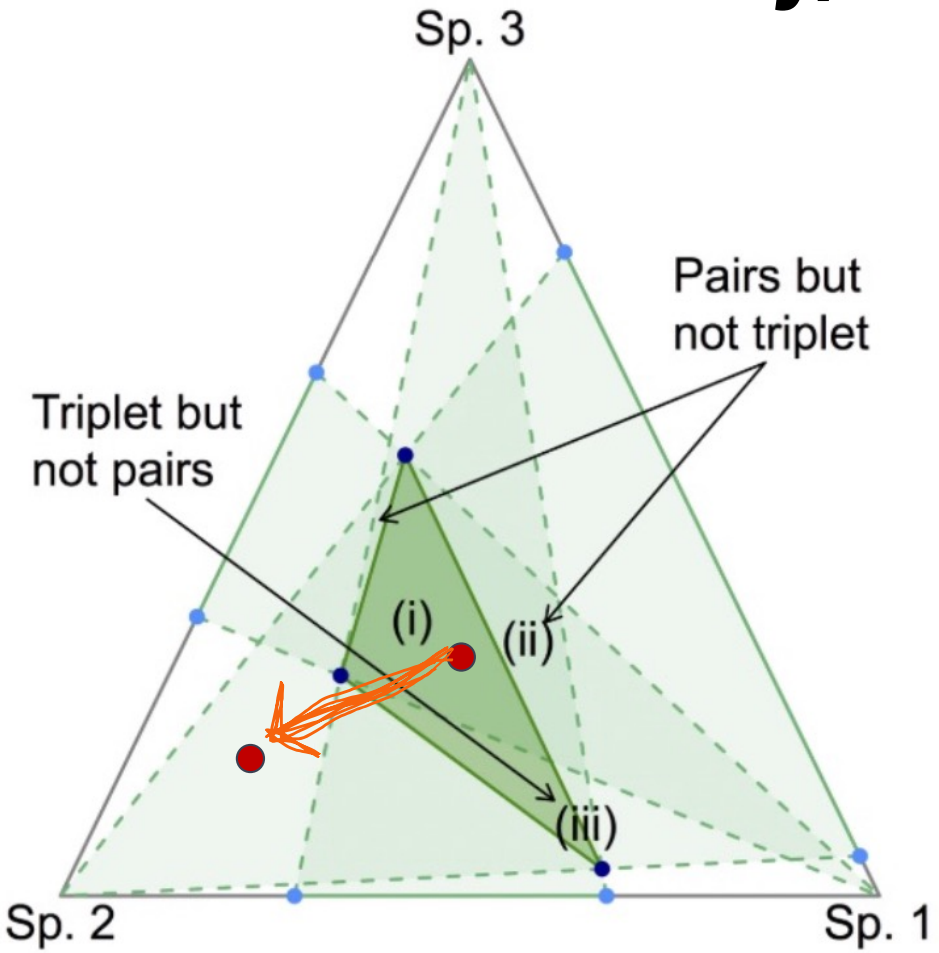
Three species

Structural Stability, 3 species



Coexistence scenario

Structural Stability, 3 species



Species 2 excluded



VOL. 203, NO. 4 THE AMERICAN NATURALIST APRIL 2024

Multitrophic Higher-Order Interactions Modulate Species Persistence

Lisa Buche,[1,*] Ignasi Bartomeus,[2] and Oscar Godoy[2,3]



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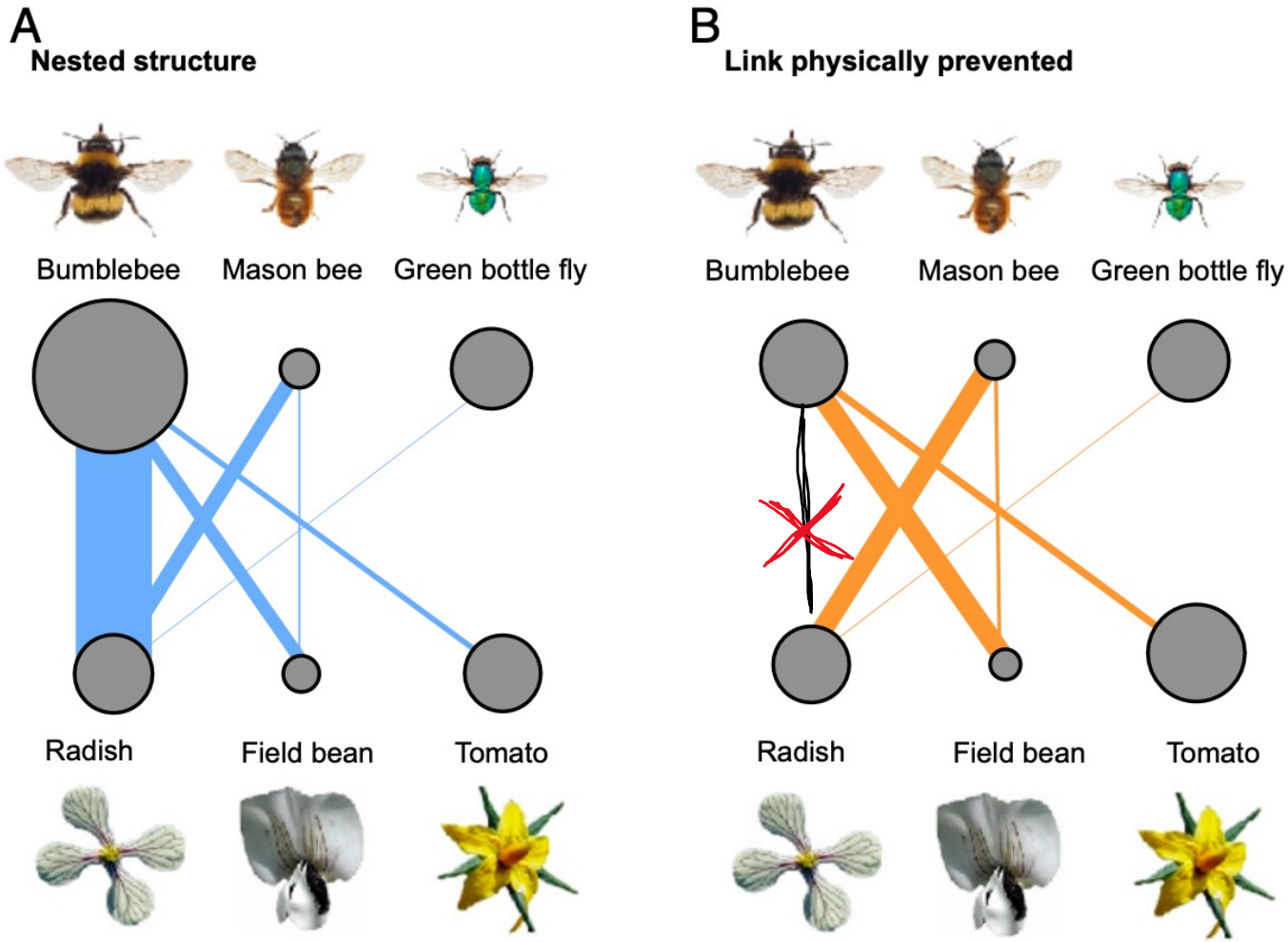
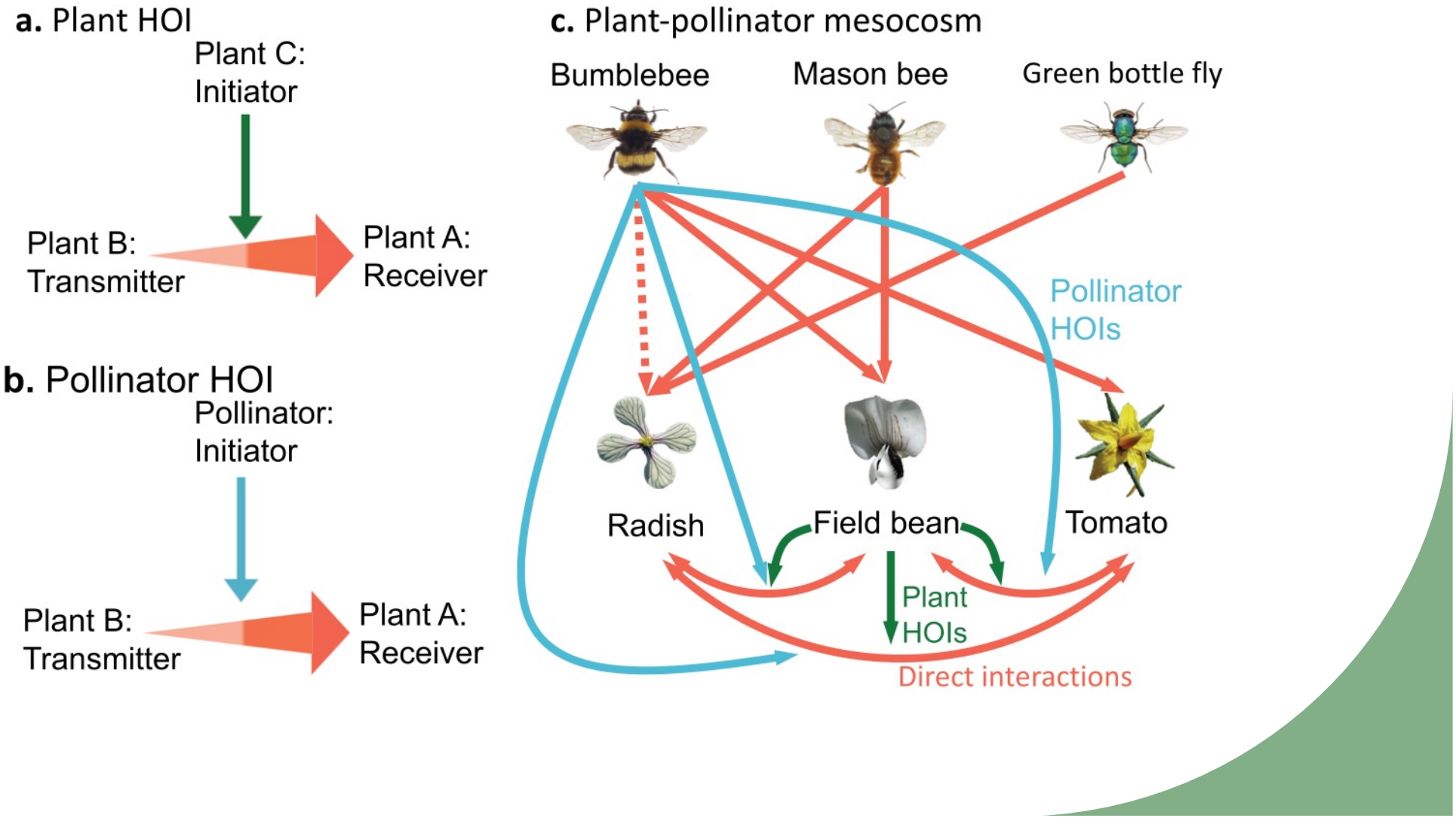
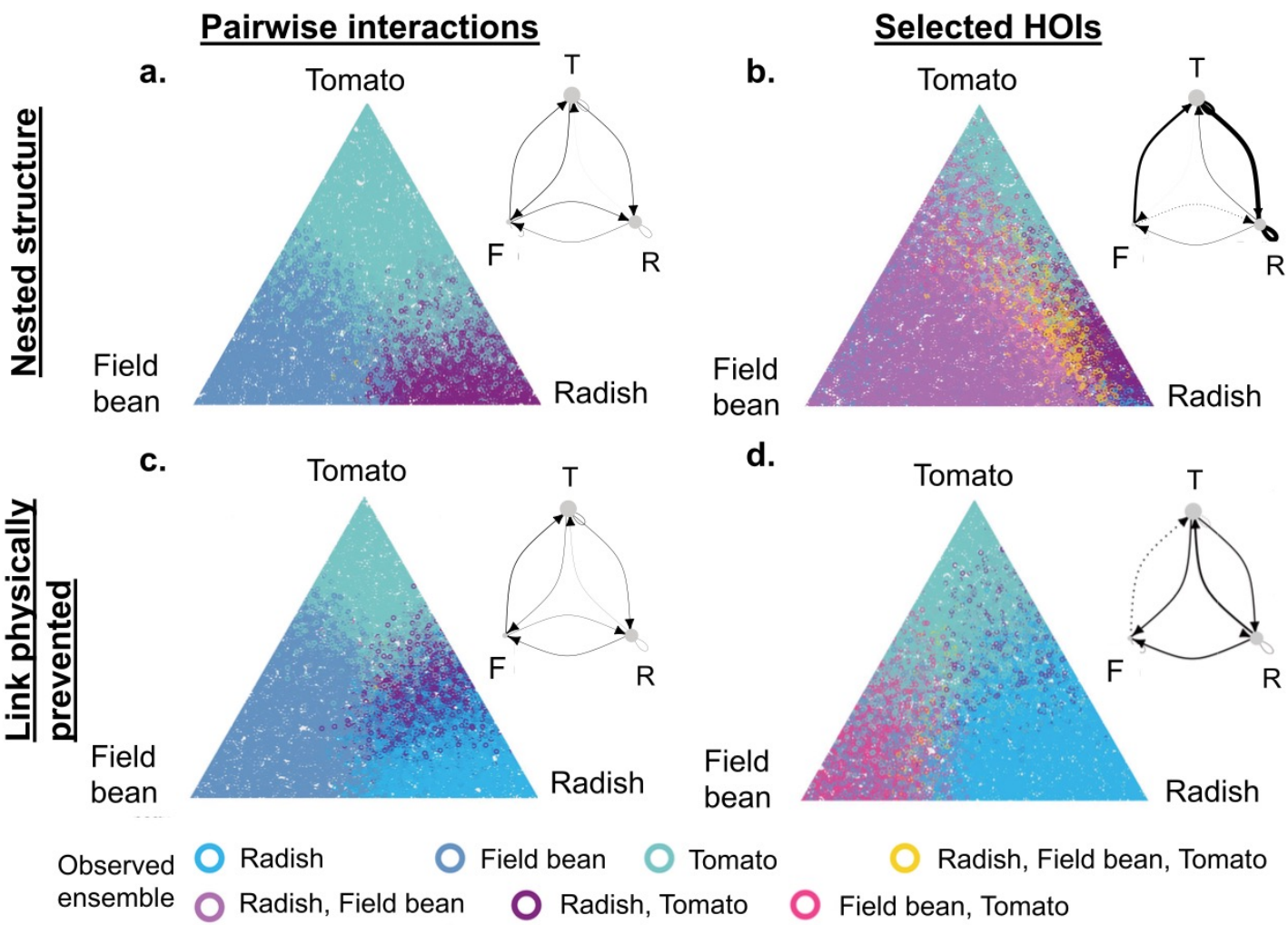
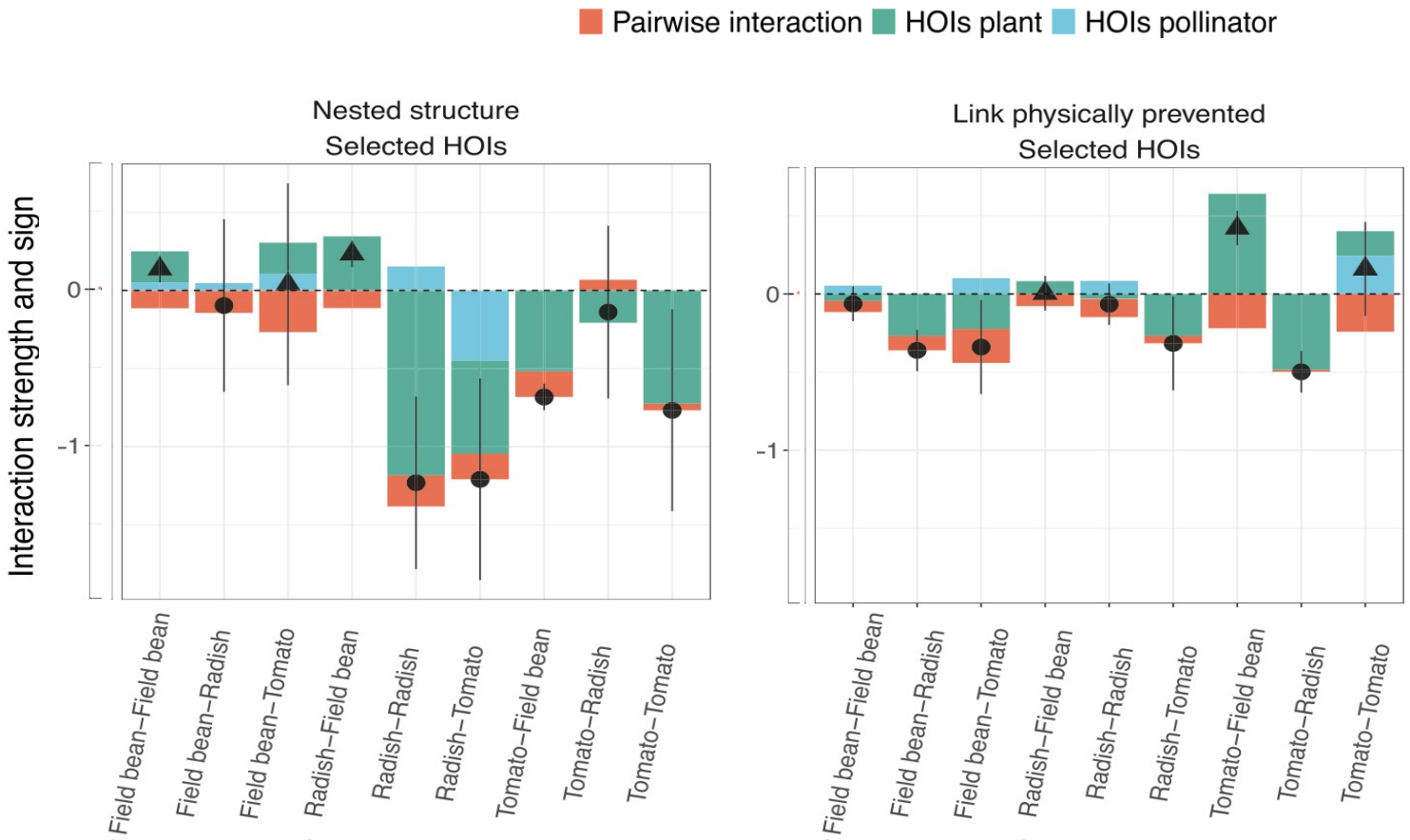
Lisa Buche,[1,*] Ignasi Bartomeus,[2] and Oscar Godoy[2,3]

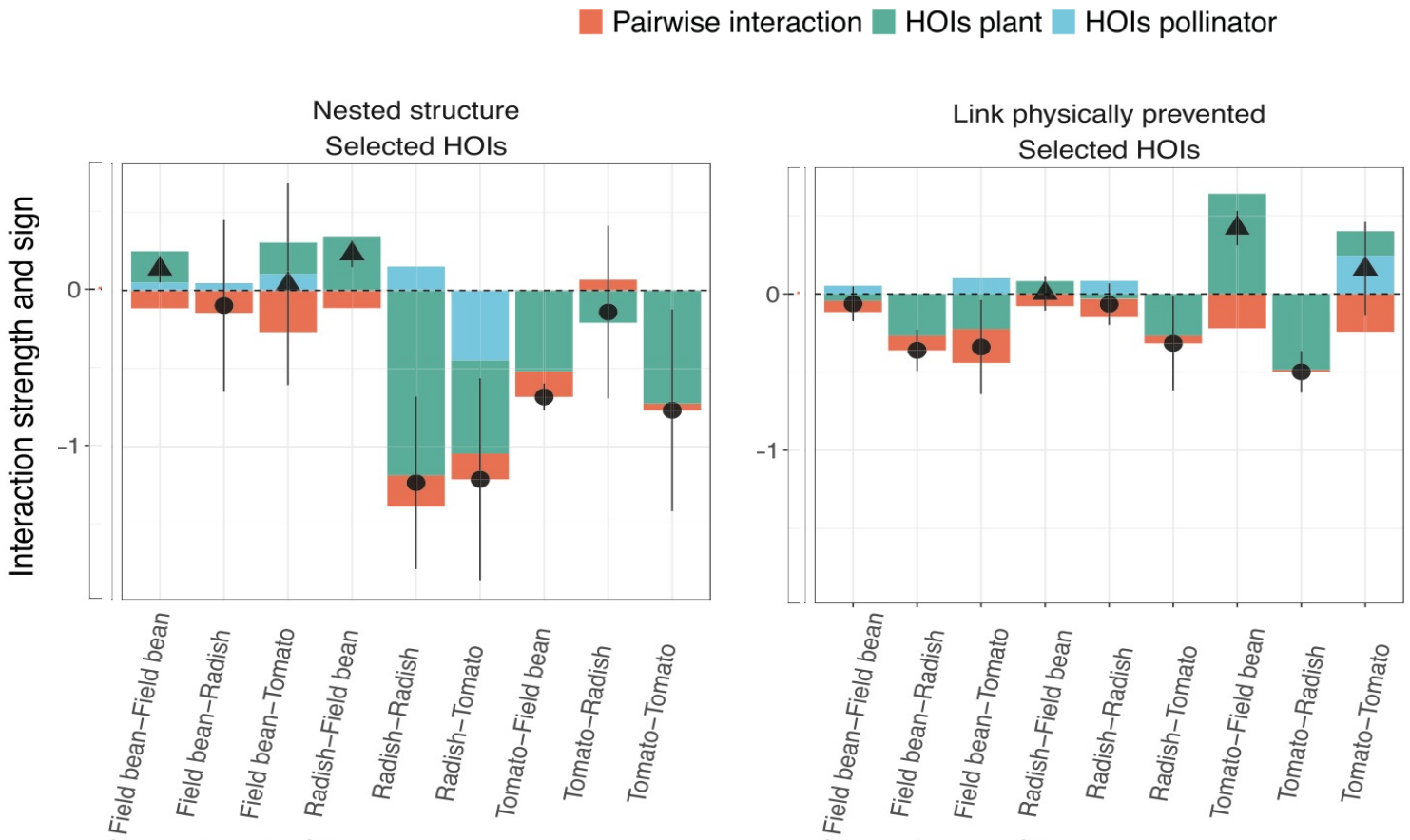
President´s Award prize 2025,
The American Naturalist


A
Nested structure
Bumblebee
Mason bee
Green bottle fly
Radish
Field bean
Tomato
B
Link physically prevented
Bumblebee
Mason bee
Green bottle fly
Radish
Field bean
Tomato


a. Plant HOI
Plant C:
Initiator
Plant B:
Transmitter
Plant A:
Receiver
b. Pollinator HOI
Pollinator:
Initiator
Plant B:
Transmitter
Plant A:
Receiver
c. Plant-pollinator mesocosm
Bumblebee
Mason bee
Green bottle fly
Pollinator
HOIs
Radish
Field bean
Tomato
Plant
HOIs
Direct interactions


Pairwise interactions
Selected HOIs
Nested structure
Link physically prevented
a.
b.
c.
d.
Tomato
Field bean
Radish
T
F
R
Observed ensemble
Radish
Field bean
Tomato
Radish, Field bean, Tomato
Radish, Field bean
Radish, Tomato
Field bean, Tomato


Pairwise interaction
HOIs plant
HOIs pollinator
Nested structure
Selected HOIs
Link physically prevented
Selected HOIs
Interaction strength and sign
0
−1
Field bean–Field bean
Field bean–Radish
Field bean–Tomato
Radish–Field bean
Radish–Radish
Radish–Tomato
Tomato–Field bean
Tomato–Radish
Tomato–Tomato



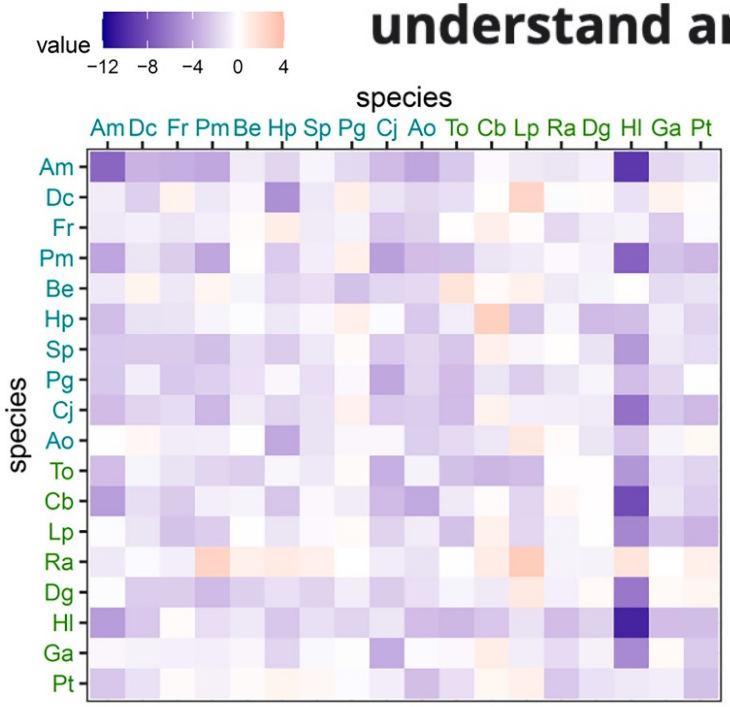
- HOIs promote facilitation that enlarges coexistence opportunities



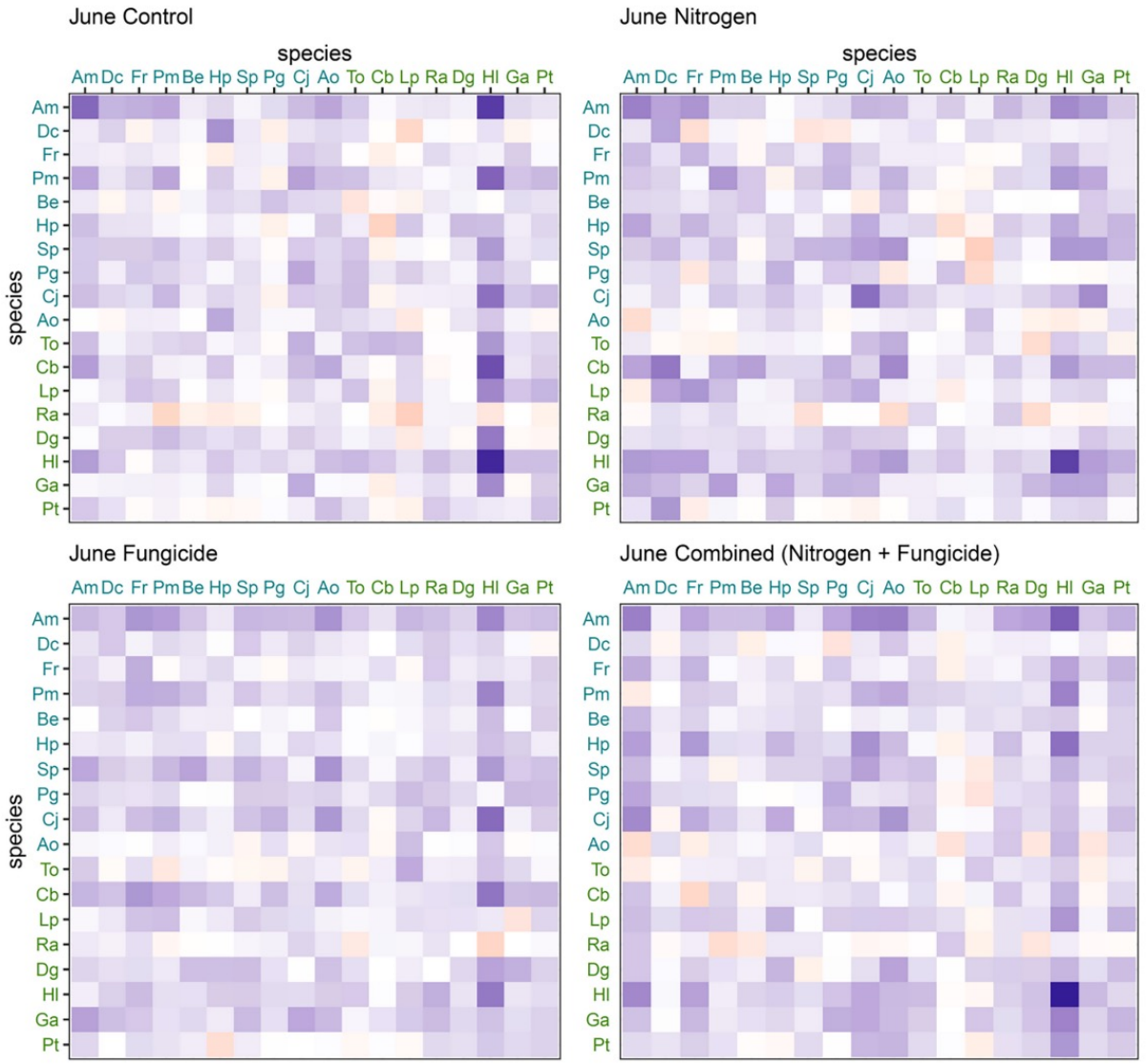
ECOLOGY LETTERS

PERSPECTIVE

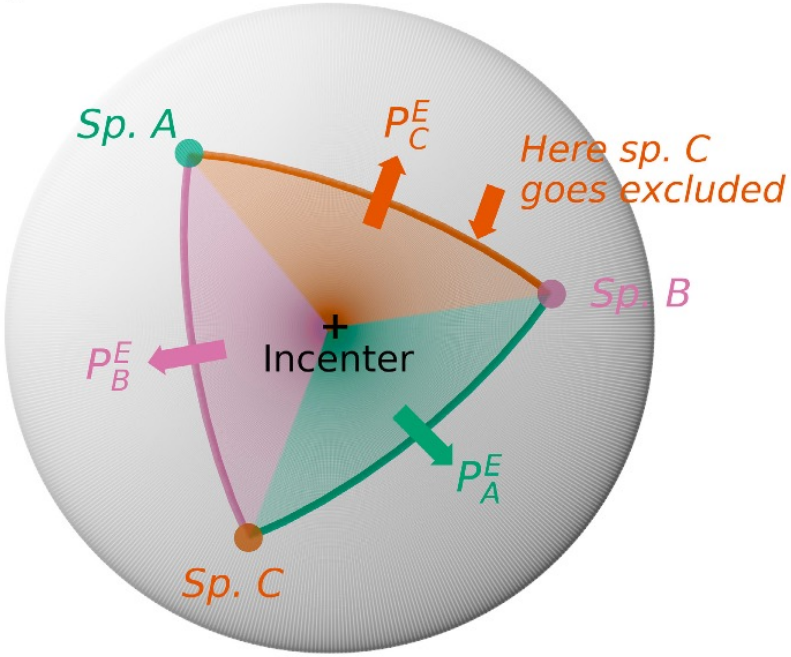
Structural asymmetry in biotic interactions as a tool to understand and predict ecological persistence



- A universal feature of nature is that species interactions are assymetrical.

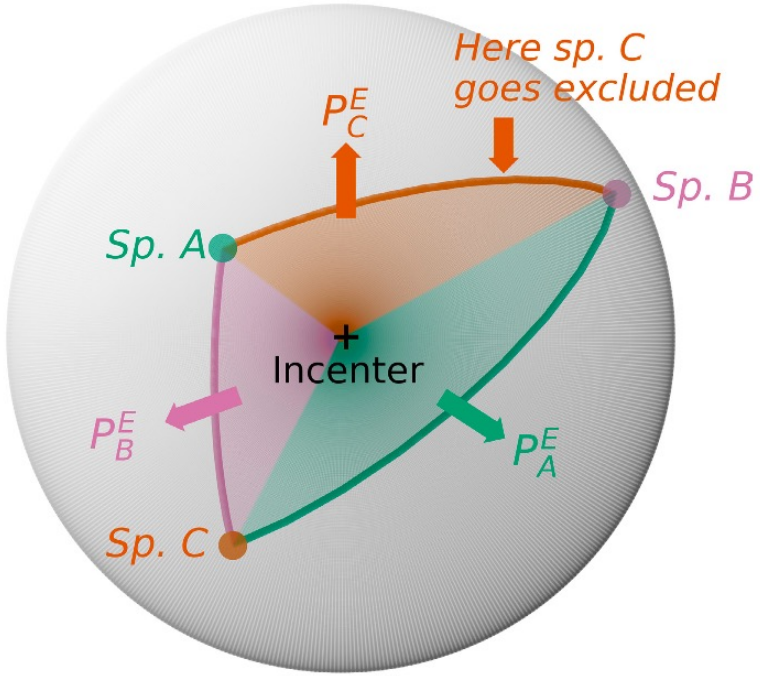

June Control
June Nitrogen
June Fungicide
June Combined (Nitrogen + Fungicide)
species
species
Am Dc Fr Pm Be Hp Sp Pg Cj Ao To Cb Lp Ra Dg Hl Ga Pt

(b) $P_i^E \equiv$ *Probability of exclusion for sp. i*



$$P_A^E = P_B^E = P_C^E$$

(c) $P_i^E \equiv$ *Probability of exclusion for sp. i*

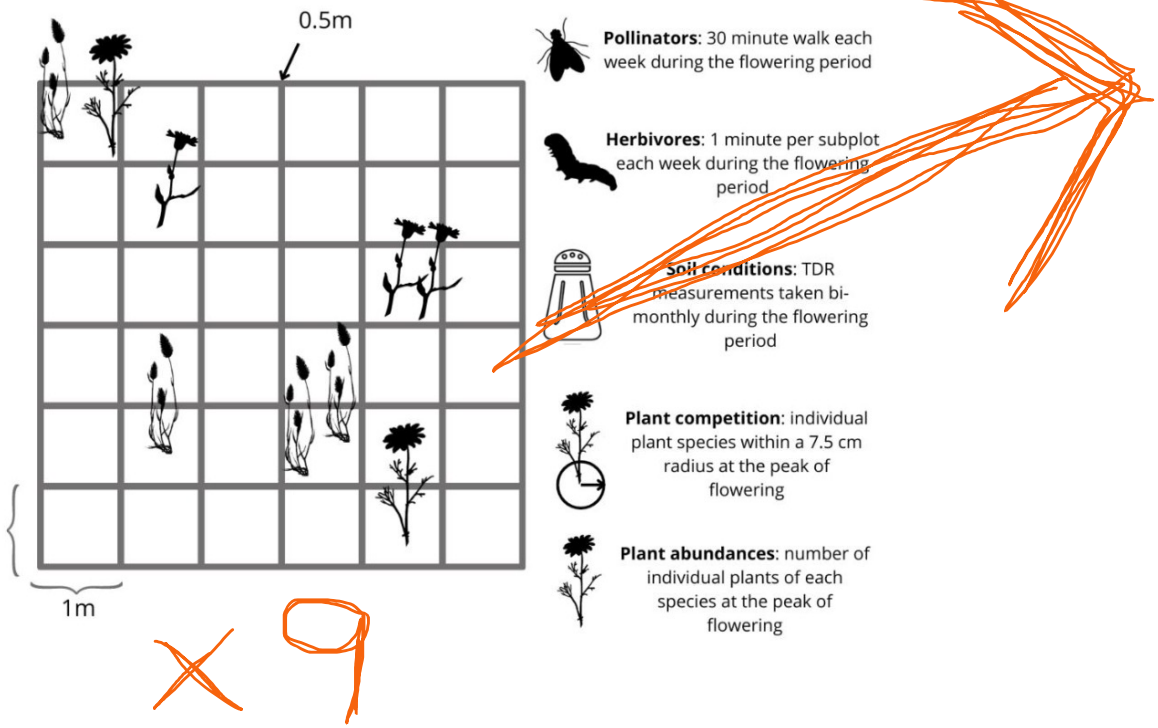


$$P_A^E > P_C^E > P_B^E$$


DOÑANA
Mar Mediterráneo
Océano
Atlántico

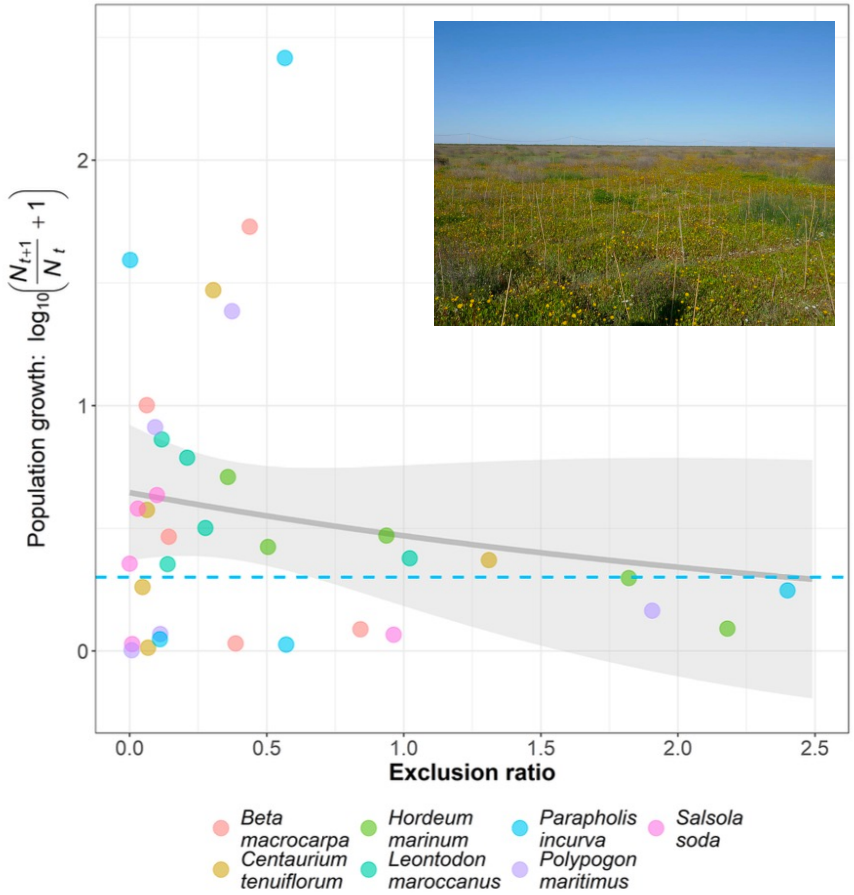


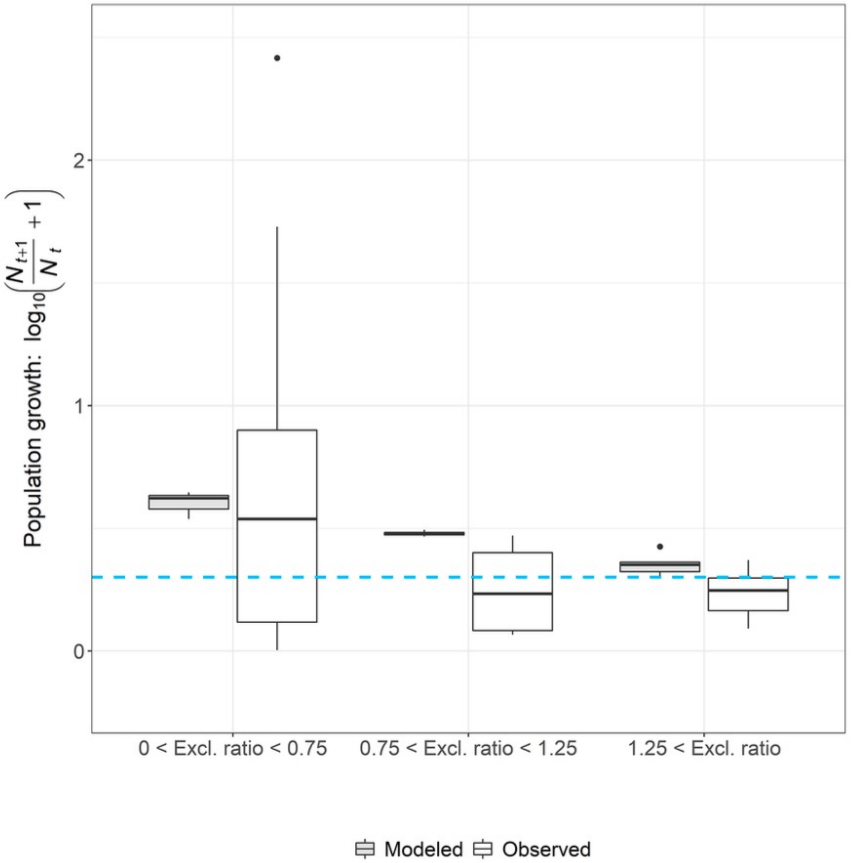
Environmental heterogeneity

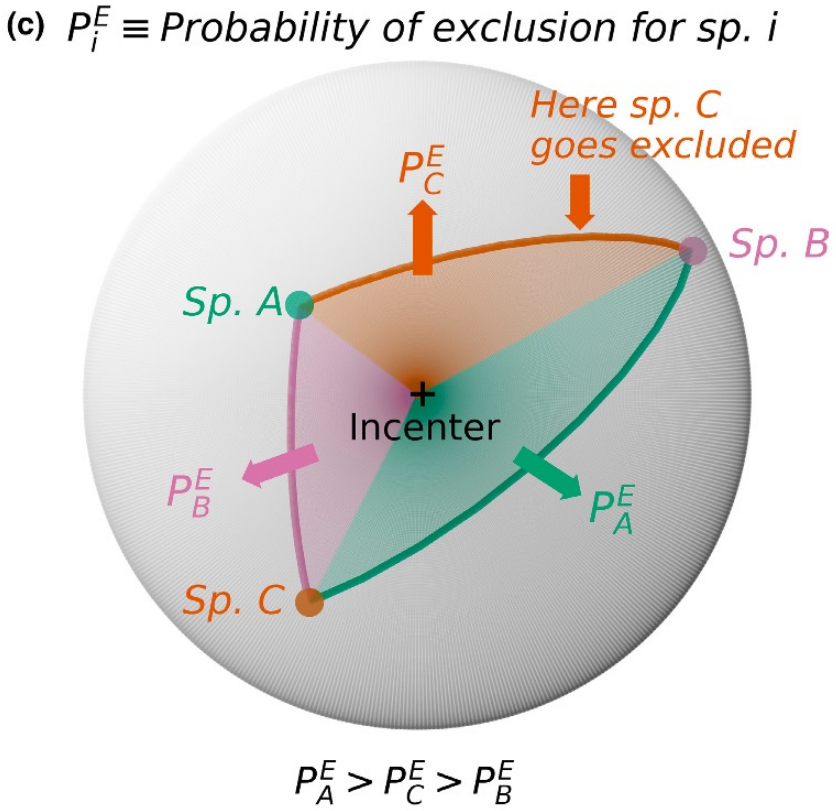


Pairiwise interactions




Population growth: $\log_{10}\left(\frac{N_{t+1}}{N_t}+1\right)$
2
1
0
0.0
0.5
1.0
1.5
2.0
2.5
Exclusion ratio
Beta macrocarpa
Centaurium tenuiflorum
Hordeum marinum
Leontodon maroccanus
Parapholis incurva
Polypogon maritimus
Salsola soda


Population growth: $\log_{10}\left(\frac{N_{t+1}}{N_t}+1\right)$
2
1
0
0 < Excl. ratio < 0.75
0.75 < Excl. ratio < 1.25
1.25 < Excl. ratio
Modeled
Observed



- The assymetry in biotic interactions provides information of future population growth.
- We can both understand which species can coexist but also predict short-term changes in future population abundances.

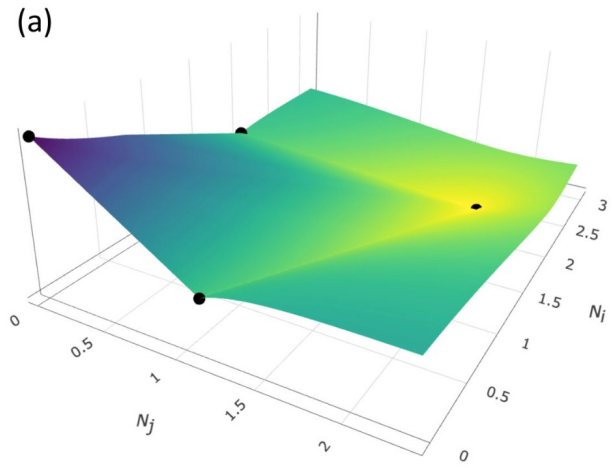
CONCEPTS & SYNTHESIS

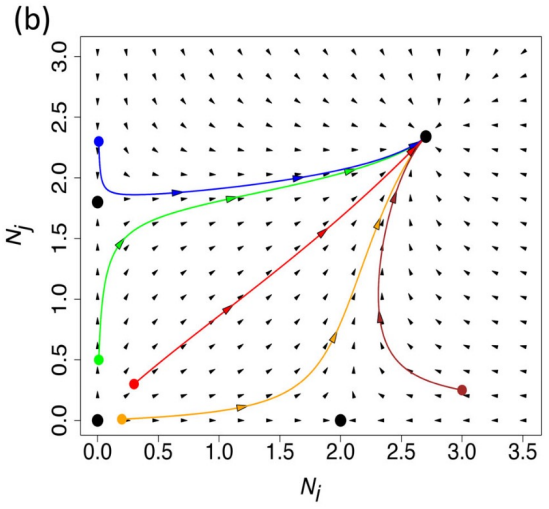
ECOLOGICAL MONOGRAPHS
ECOLOGICAL SOCIETY OF AMERICA



The assembly and dynamics of ecological communities in an ever-changing world

Oscar Godoy[1] | **Fernando Soler-Toscano**[2] | **José R. Portillo**[3,4] | **José A. Langa**[5]





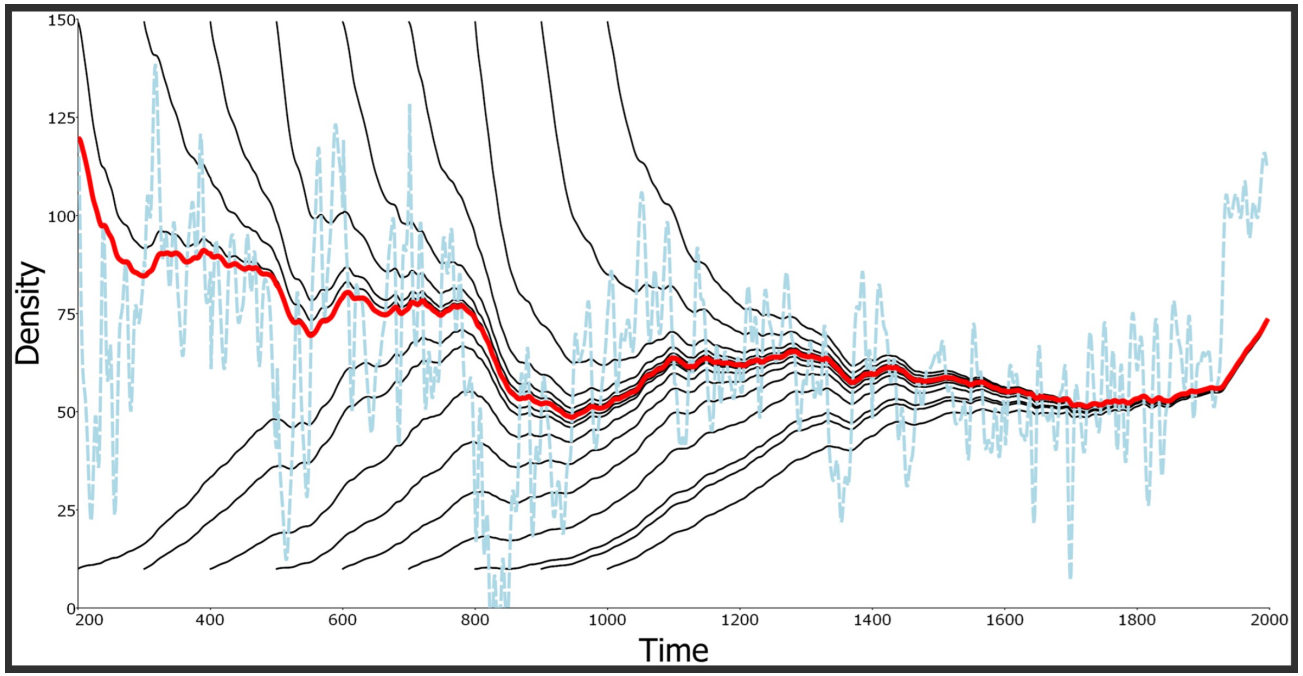
US · 1505 · MATEMÁTICAS

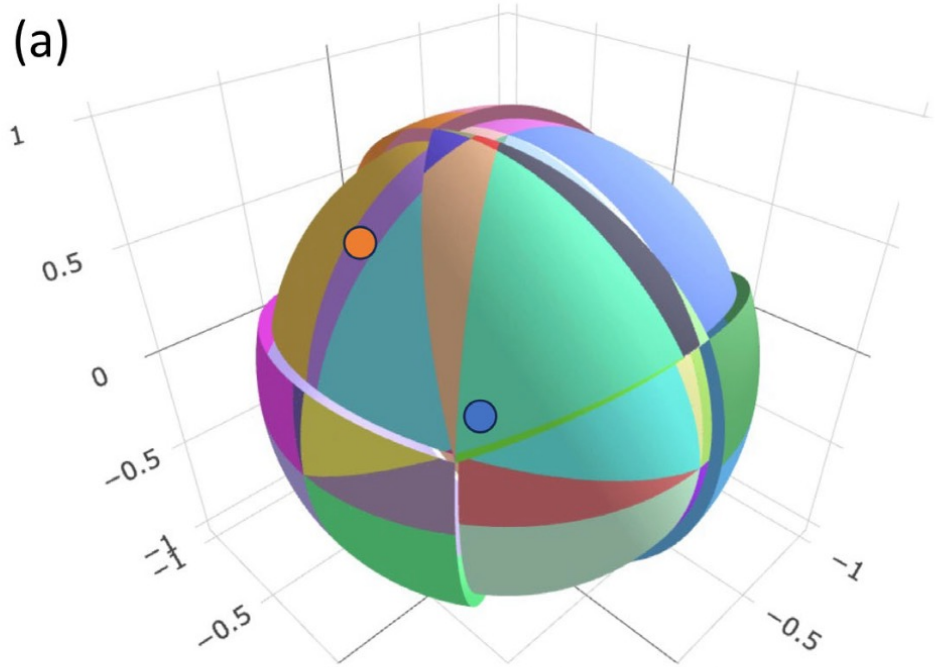
PLOS BIOLOGY

ESSAY

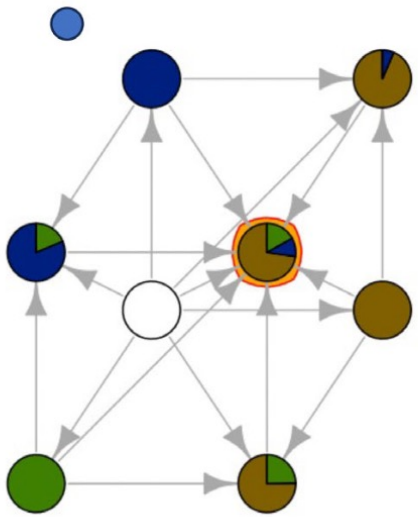
AEDT: A new concept for ecological dynamics in the ever-changing world

Peter Chesson[1,2]*

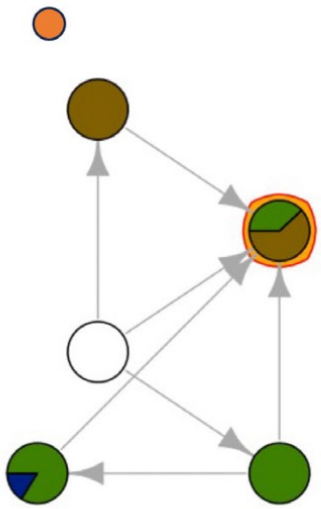




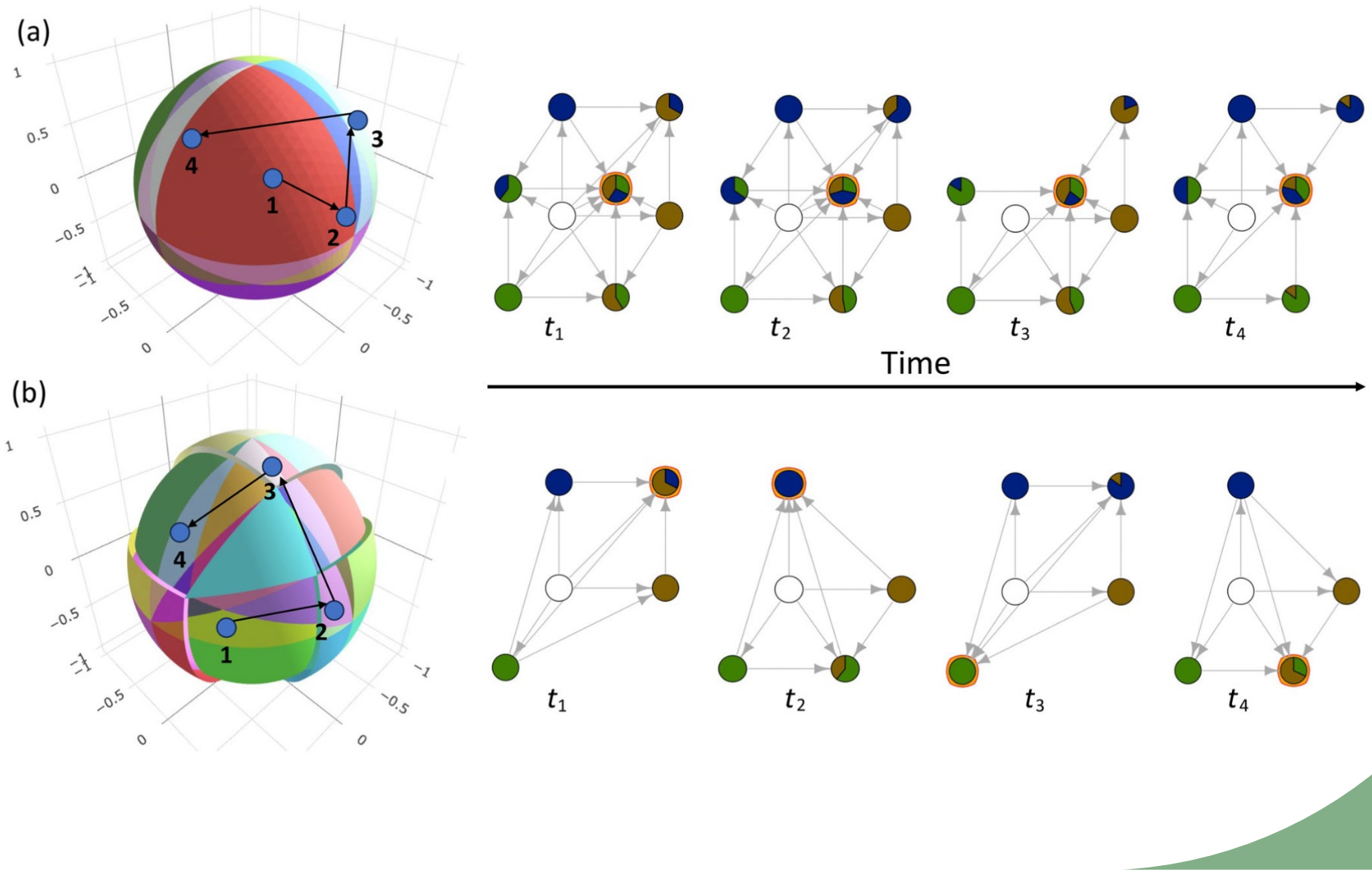
$$\mathbf{A} = \begin{bmatrix} -1 & 0.06 & -0.18 \\ -0.71 & -1 & 0.20 \\ -0.35 & -0.55 & 1 \end{bmatrix}$$

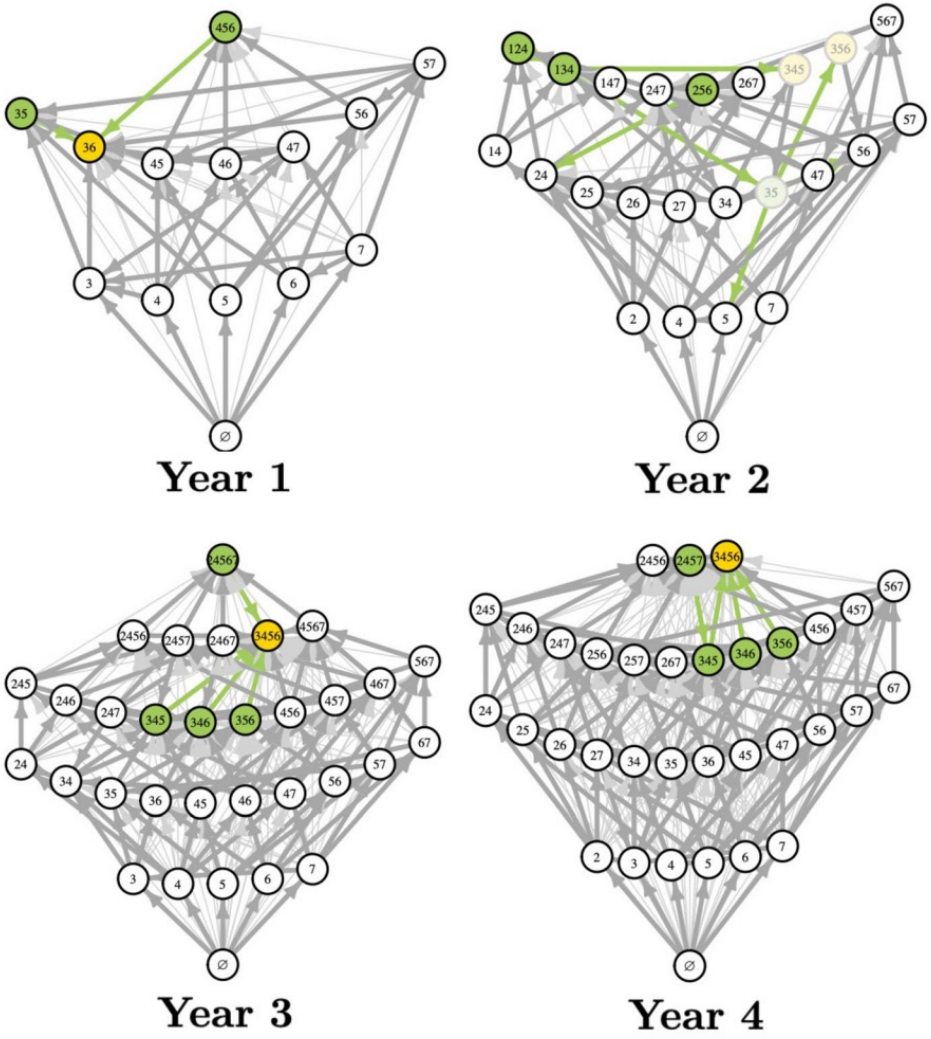


$r_1 = 0.35$
$r_2 = 0.27$
$r_3 = 0.22$

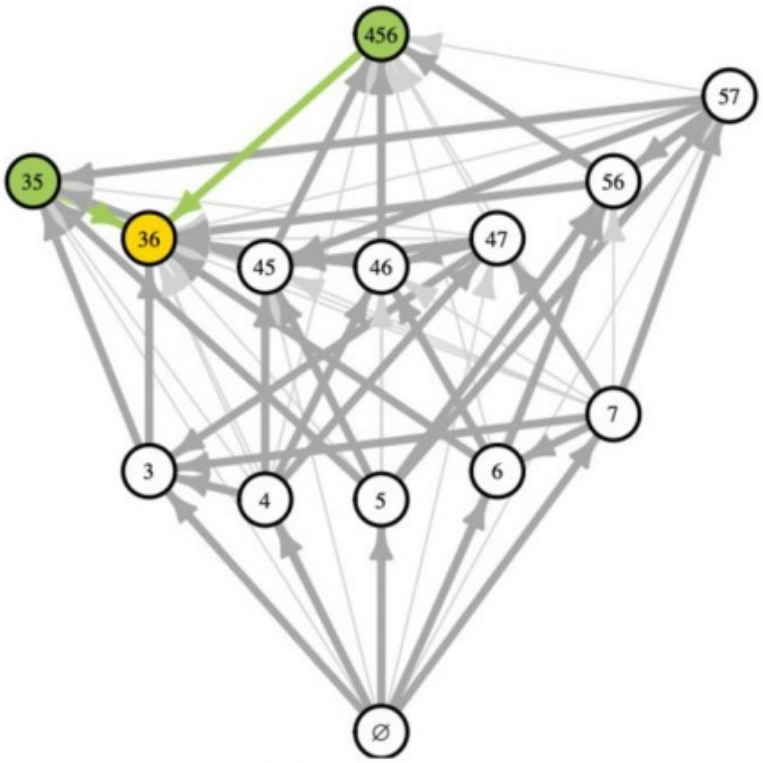


$r_1 = 0.36$
$r_2 = -0.01$
$r_3 = 0.31$

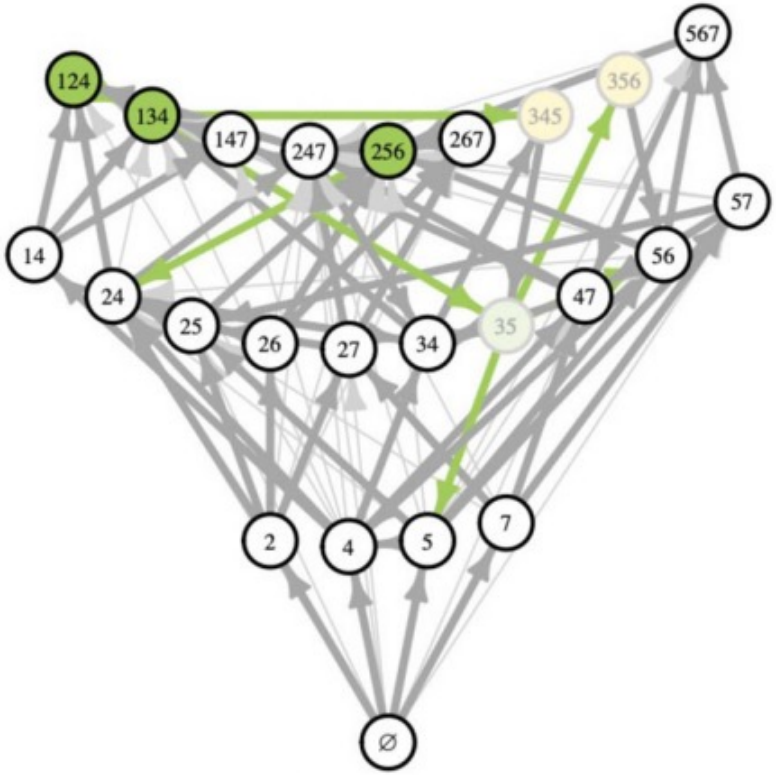

(a)
(b)
1
2
3
4
t_1
t_2
t_3
t_4
Time


456
57
35
56
36
45
46
47
7
3
4
5
6
∅
Year 1
124
134
147
247
256
267
345
356
567
57
14
24
25
26
27
34
35
47
56
2
4
5
7
∅
Year 2
3456
2456
2457
2467
4567
567
245
246
247
345
346
356
456
457
467
24
34
35
36
45
46
47
56
57
67
3
4
5
6
7
∅
Year 3
2456
2457
3456
567
245
246
247
256
257
267
345
346
356
456
457
67
24
25
26
27
34
35
36
45
47
56
57
2
3
4
5
6
7
∅
Year 4

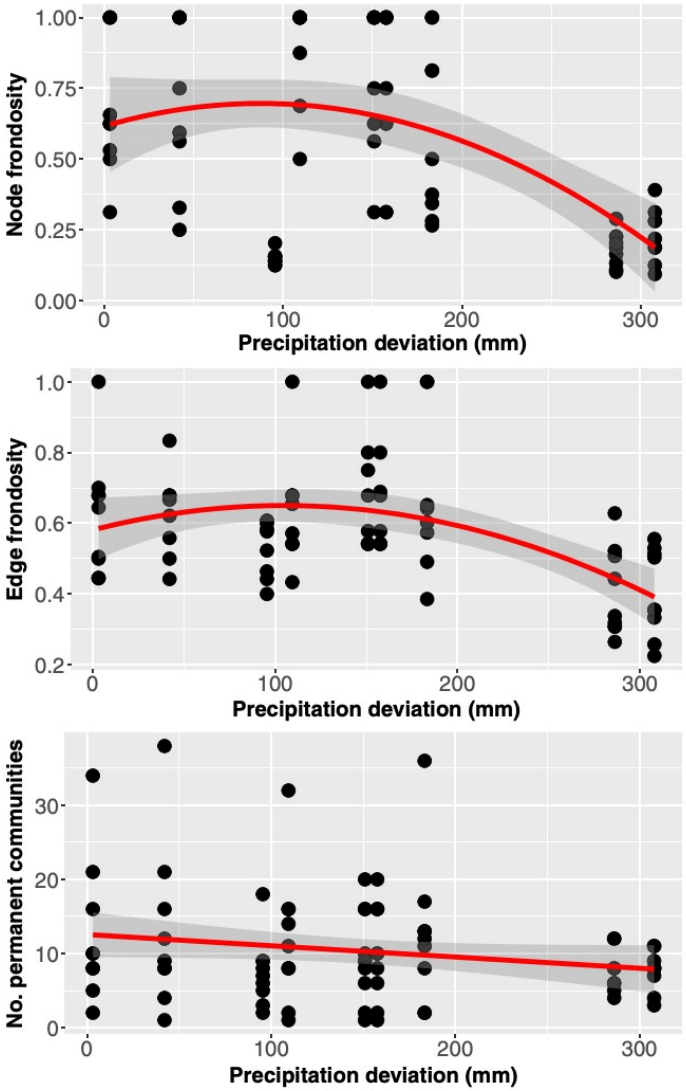


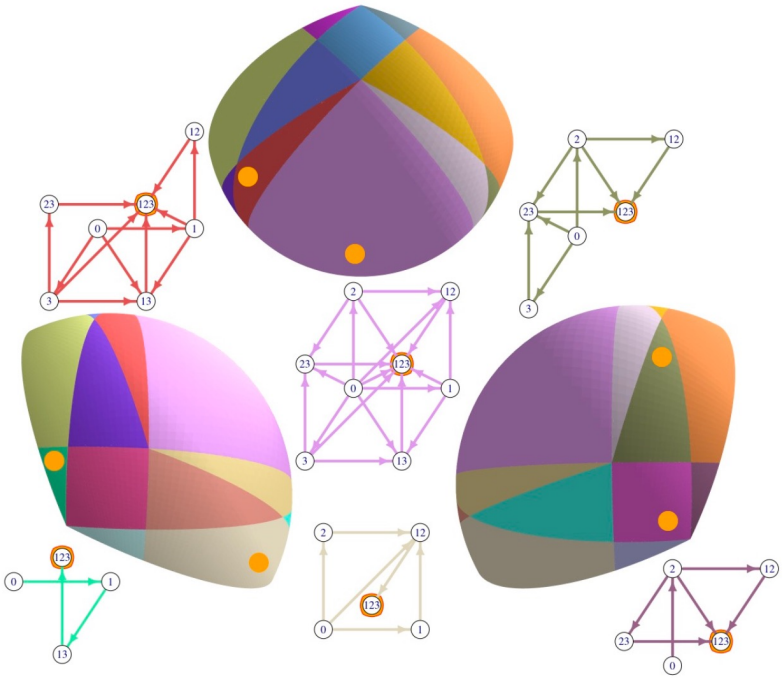

456
57
35
56
36
47
45
46
7
3
6
4
5
∅

Year 1


567
124
356
134
345
147
247
256
267
57
14
56
24
47
35
25
26
27
34
2
4
5
7
∅

Year 2


Node frondosity
1.00
0.75
0.50
0.25
0.00
0
100
200
300
Precipitation deviation (mm)
Edge frondosity
1.0
0.8
0.6
0.4
0.2
0
100
200
300
Precipitation deviation (mm)
No. permanent communities
30
20
10
0
0
100
200
300
Precipitation deviation (mm)



- Species interactions are temporally variable due to changes in climatic conditions (i.e., rainfall).
- We can evaluate how such changes modify the non-autonomous dynamics of ecological communities.



Species coexistence in an ever-changing world

Oscar Godoy

Estación Biológica Doñana CSIC