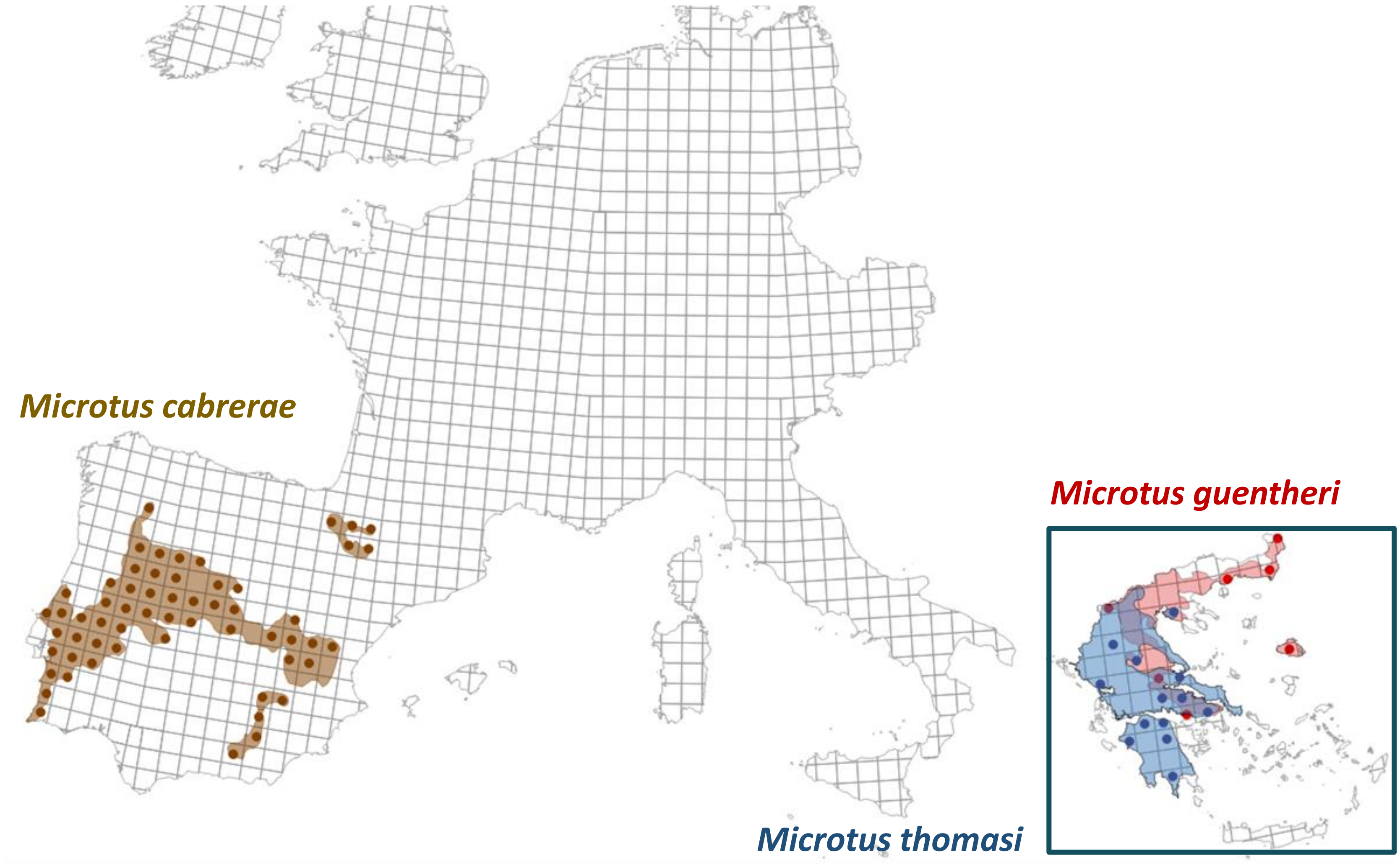
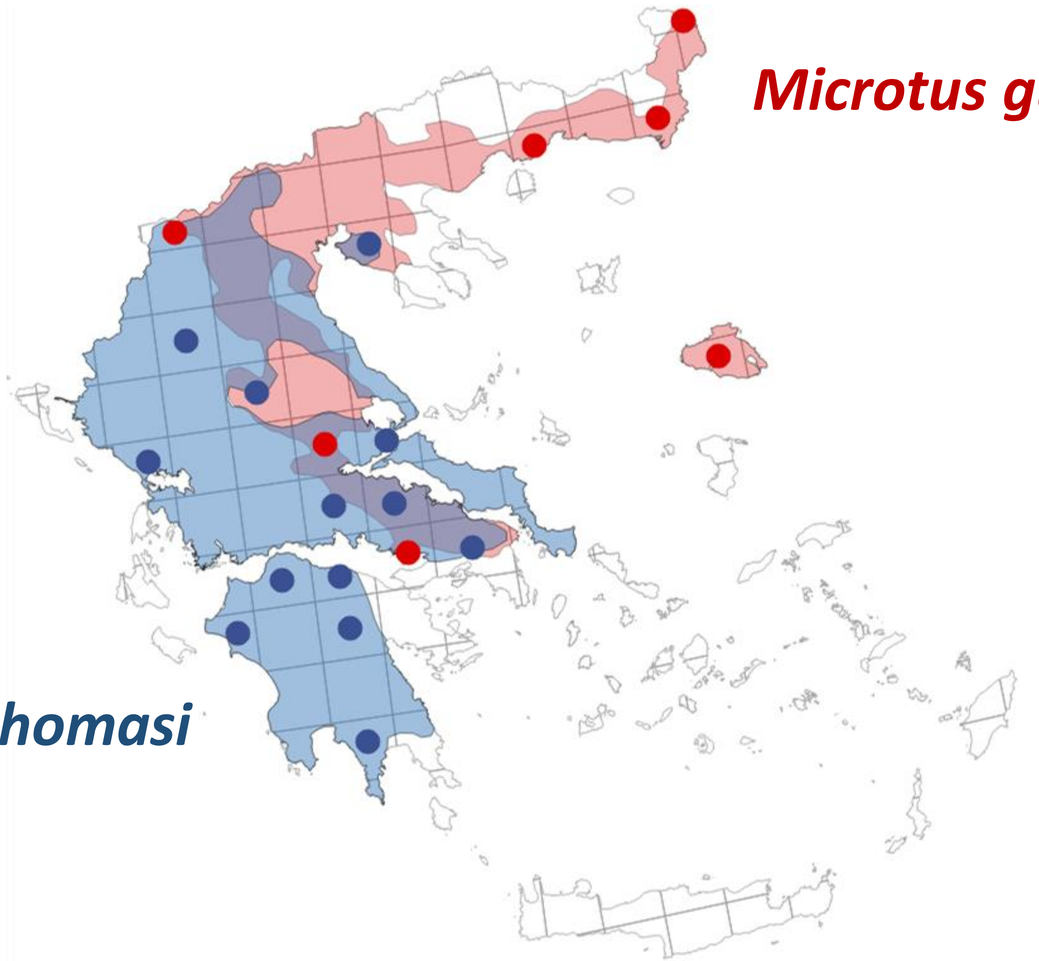
Fuzzy comparisons:

similarity, overlap and change

Similarity (overlap) between distributions



Similarity (overlap) between distributions



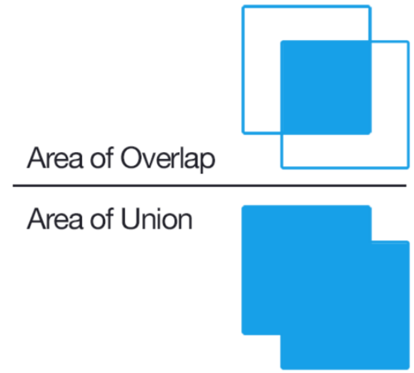
Microtus guentheri

Microtus thomasi

Similarity (overlap) between distributions

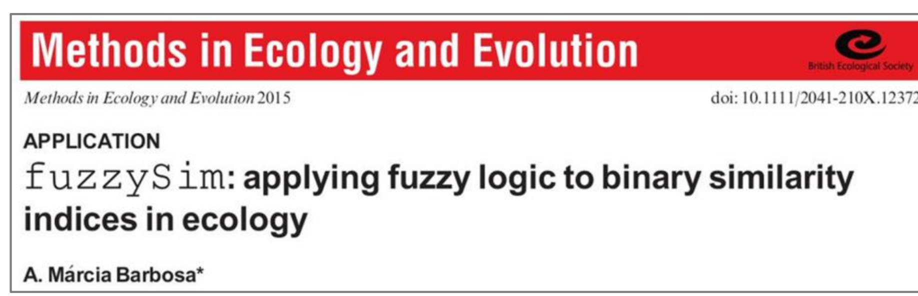
Jaccard's similarity index (e.g. to compare species distributions or biogeographic regions):

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|}$$



typically calculated by counting occupied and shared localities, so apparently requires **categorical data**…

…but **not necessarily**!


Methods in Ecology and Evolution

British Ecological Society

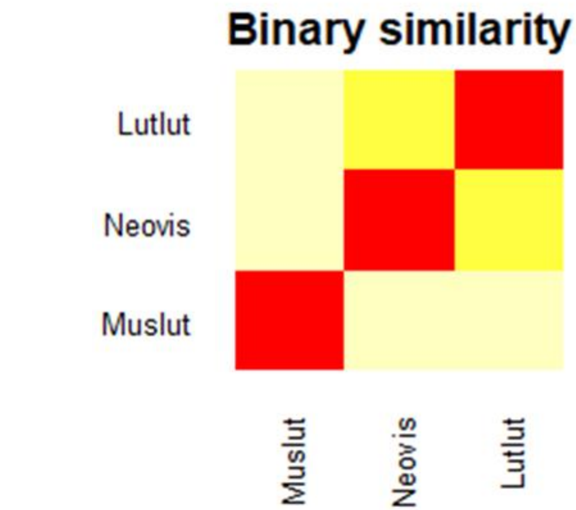
Methods in Ecology and Evolution 2015 doi: 10.1111/2041-210X.12372

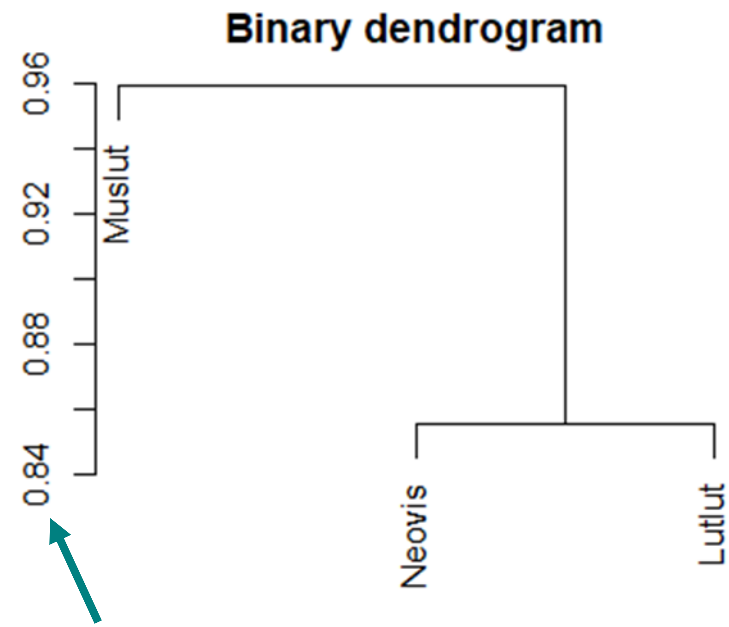
APPLICATION

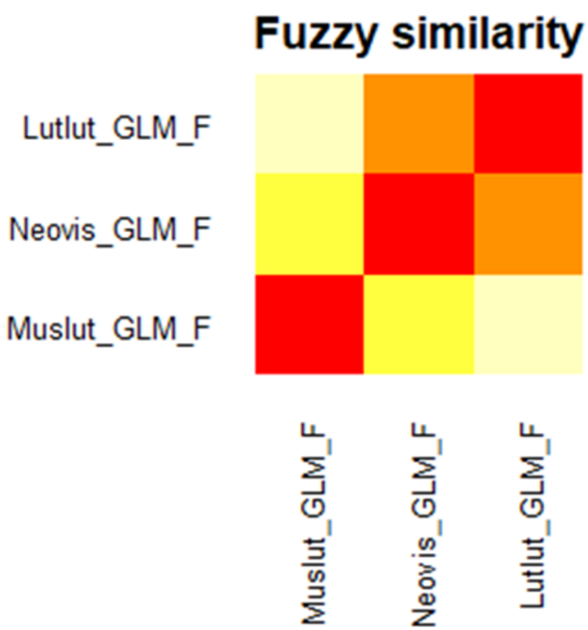
`fuzzySim`: applying fuzzy logic to binary similarity indices in ecology

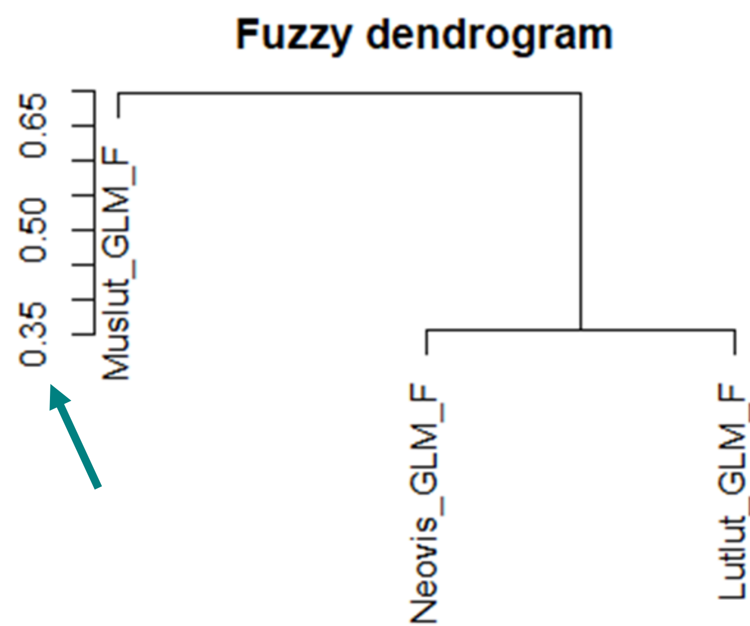
A. Márcia Barbosa*

Similarity (overlap) between distributions







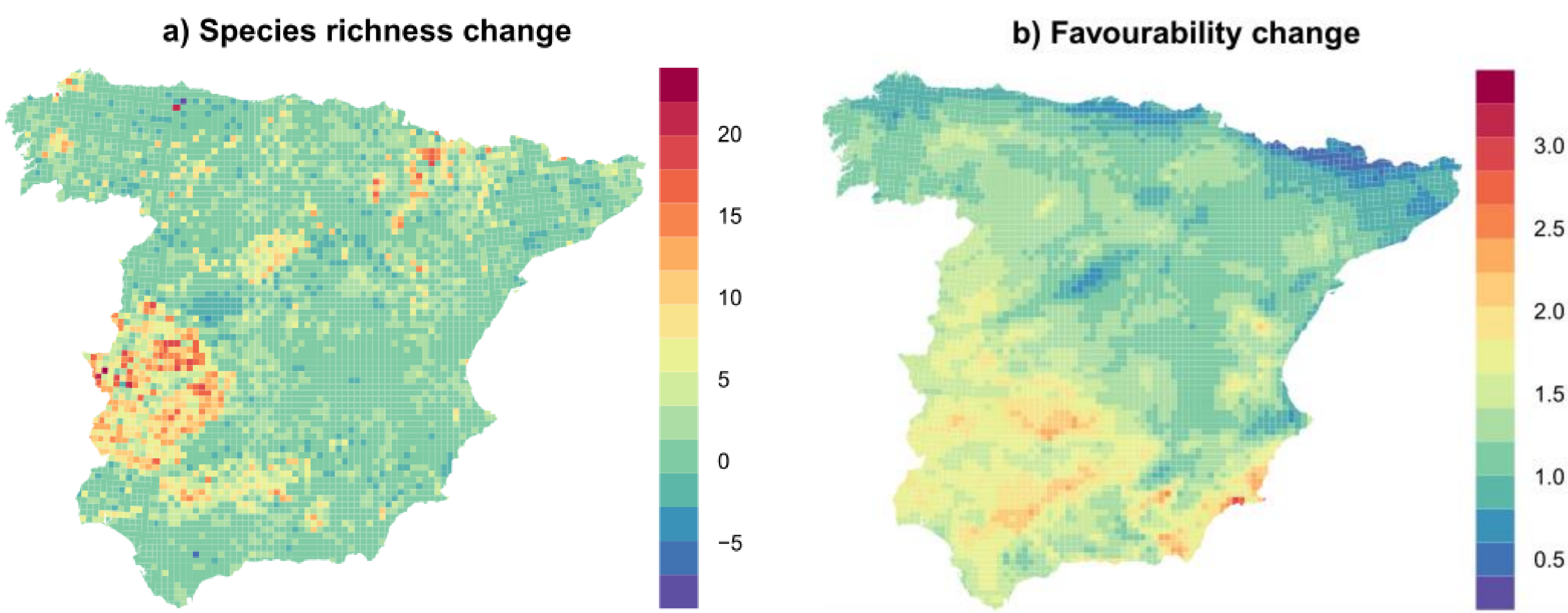


Changes in species distributions

size of area of expansion / contraction

number of new (gained) / lost presences

fuzzy version: change in favourability sum



Changes in species distributions

size of area of expansion / contraction

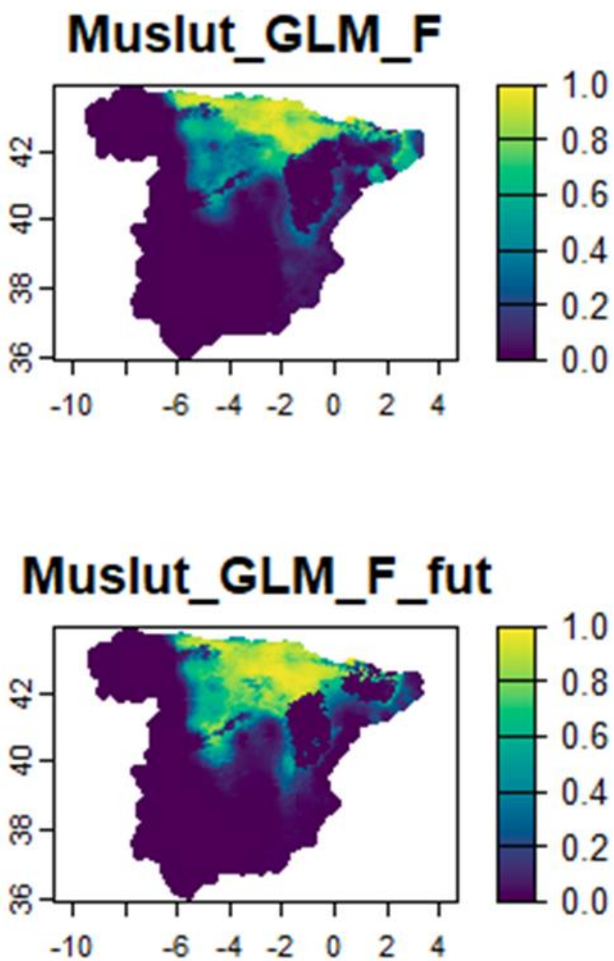
number of new (gained) / lost presences

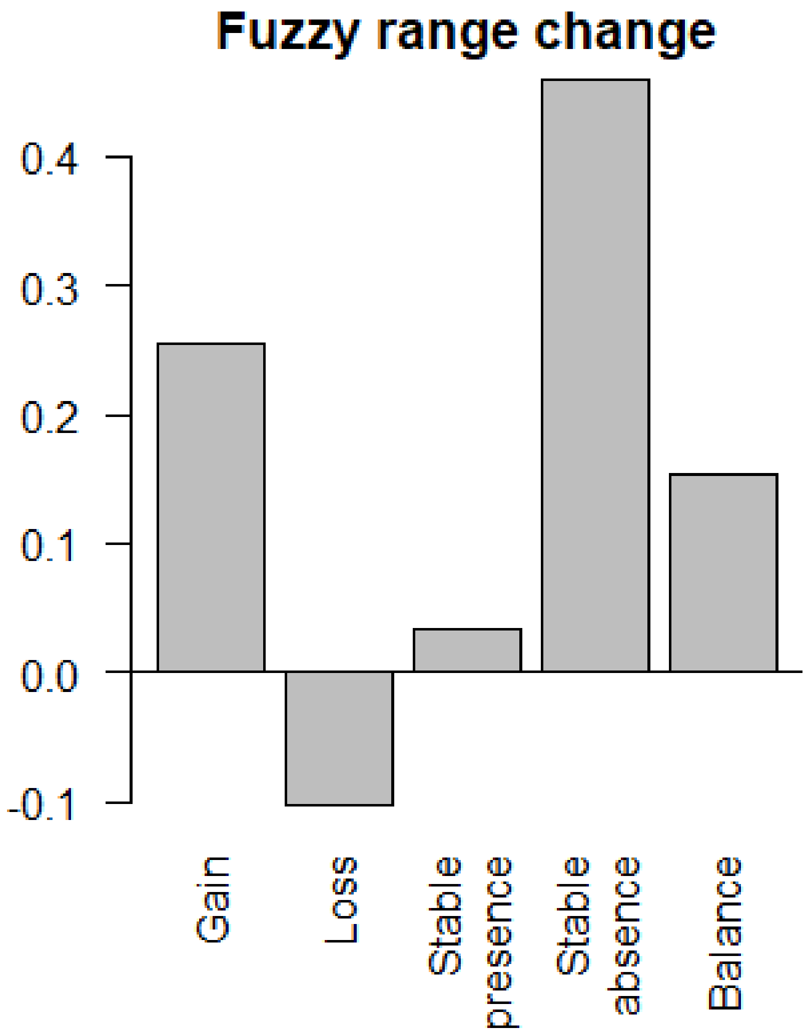
fuzzy version: change in favourability sum

range increase (gain): sum of the predicted values that have increased from pred1 to pred2 (fuzzy equivalent of the number of gained presences)

range decrease (loss): sum of the predicted values that have decreased from pred1 to pred2 (fuzzy equivalent of the number of lost presences)

Changes in species distributions





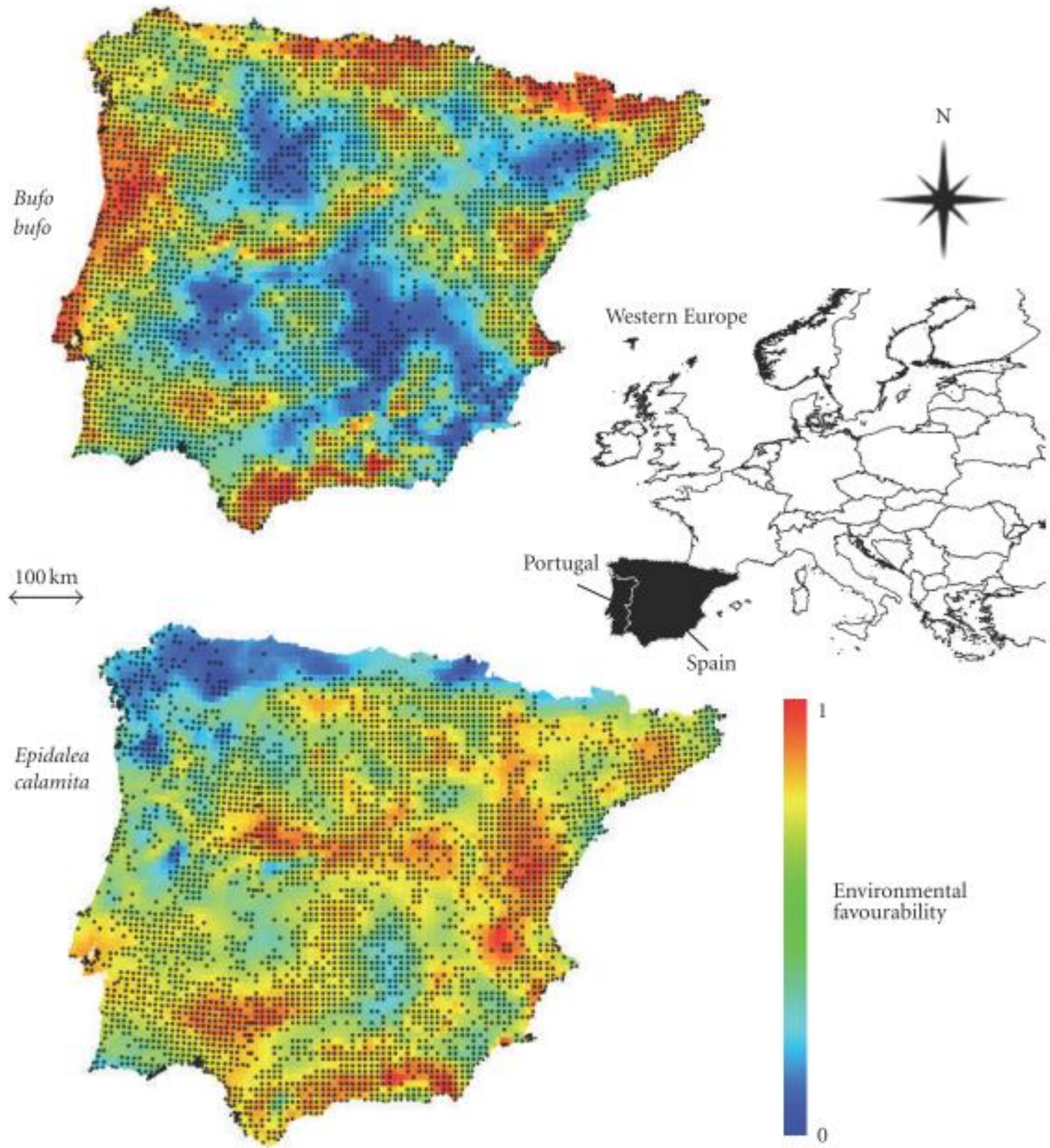
Case study

The Scientific World Journal
Volume 2012, Article ID 428206, 10 pages
doi:10.1100/2012/428206

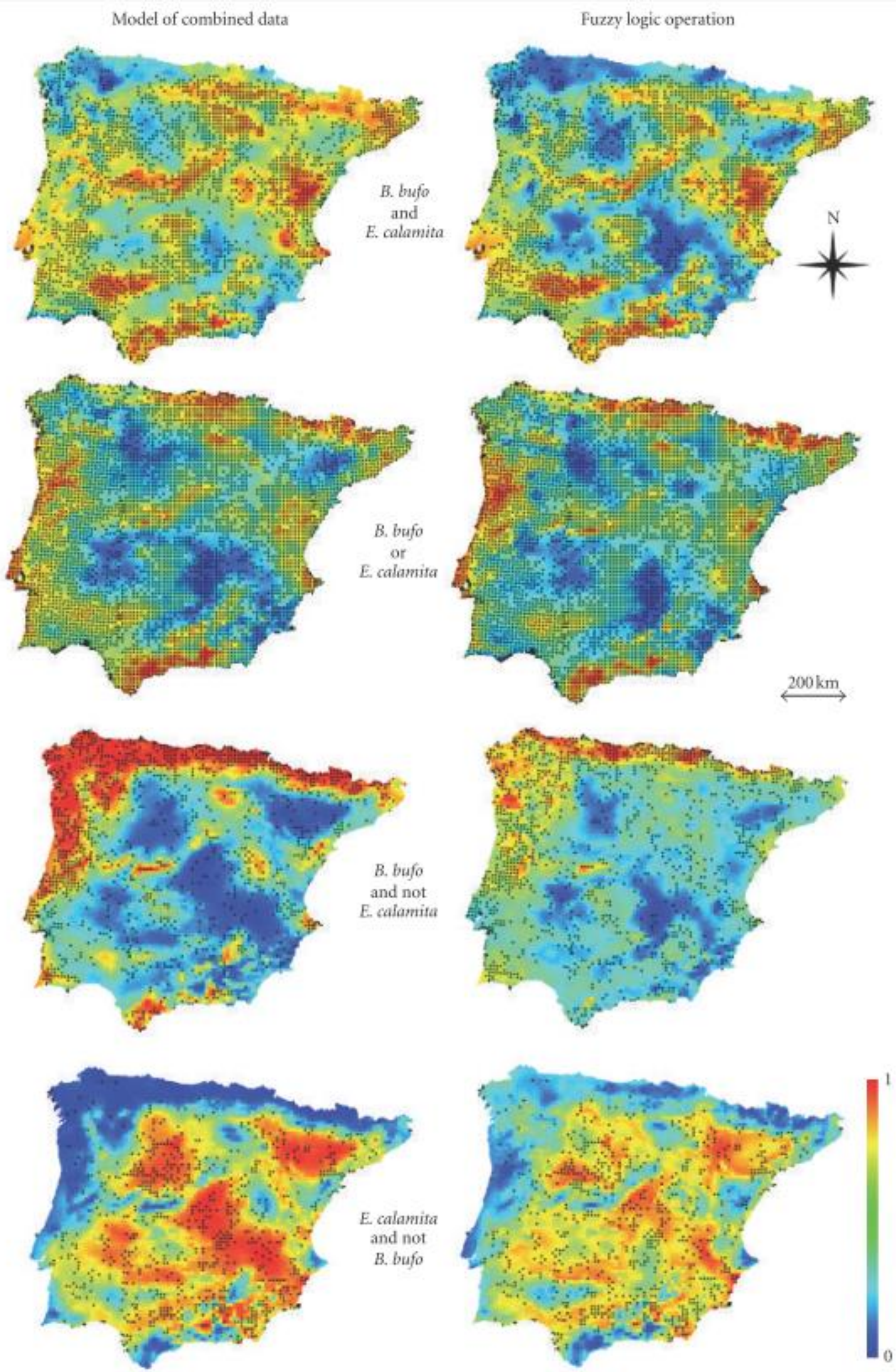
Research Article

Applying Fuzzy Logic to Comparative Distribution Modelling: A Case Study with Two Sympatric Amphibians

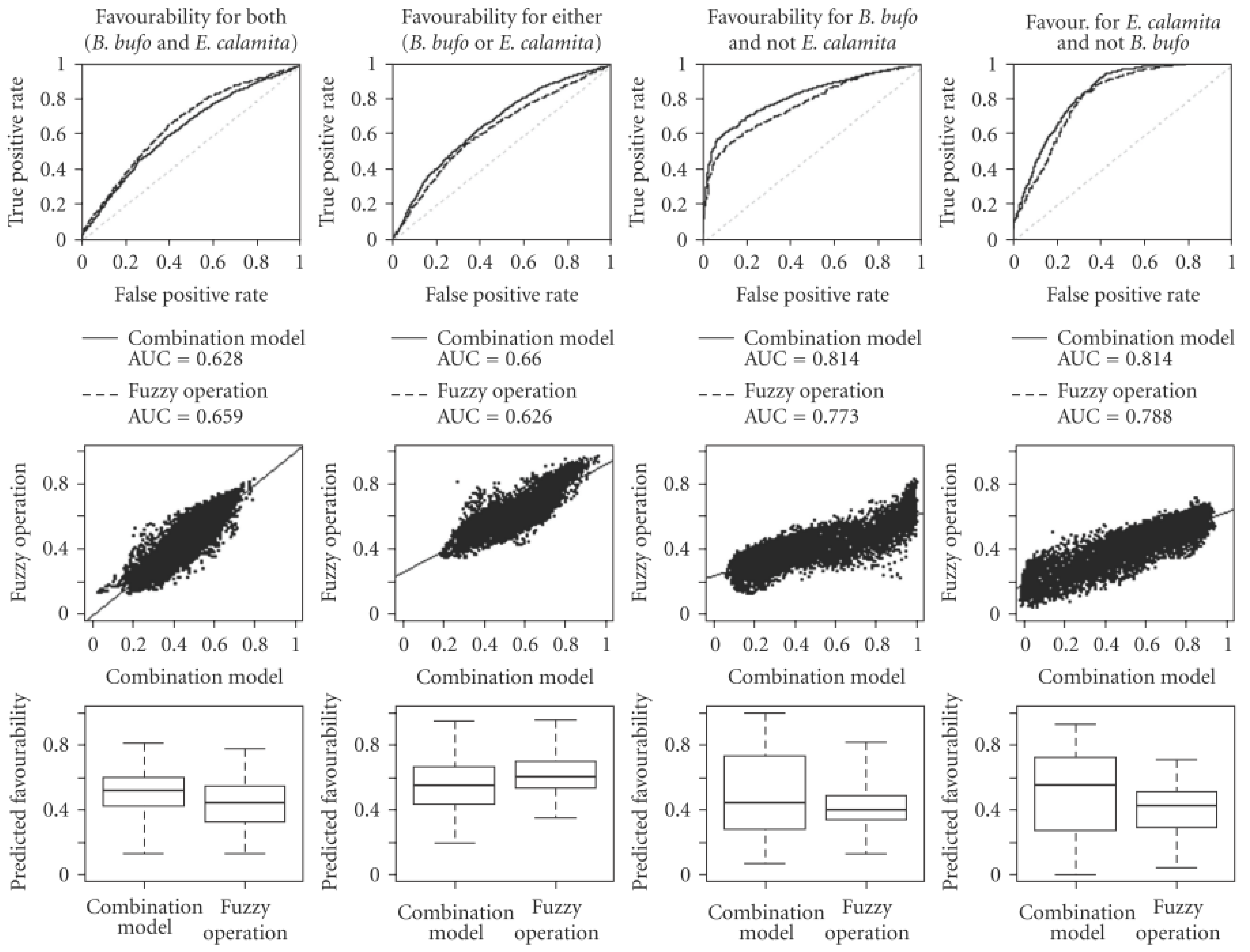
A. Márcia Barbosa[1,2] and Raimundo Real[3]



Recorded occurrence and favourability for *Bufo bufo* and *E. calamita.*



Comparison of favourability for *Bufo bufo* and *E. calamita* given by the models of combined presence/absence data and by fuzzy logic operations between the individual species models.



Favourability for both (B. bufo and E. calamita)
Favourability for either (B. bufo or E. calamita)
Favourability for B. bufo and not E. calamita
Favour. for E. calamita and not B. bufo
True positive rate
False positive rate
Combination model AUC = 0.628
Fuzzy operation AUC = 0.659
Combination model AUC = 0.66
Fuzzy operation AUC = 0.626
Combination model AUC = 0.814
Fuzzy operation AUC = 0.773
Combination model AUC = 0.814
Fuzzy operation AUC = 0.788
Fuzzy operation
Combination model
Predicted favourability
Combination model
Fuzzy operation

Case study

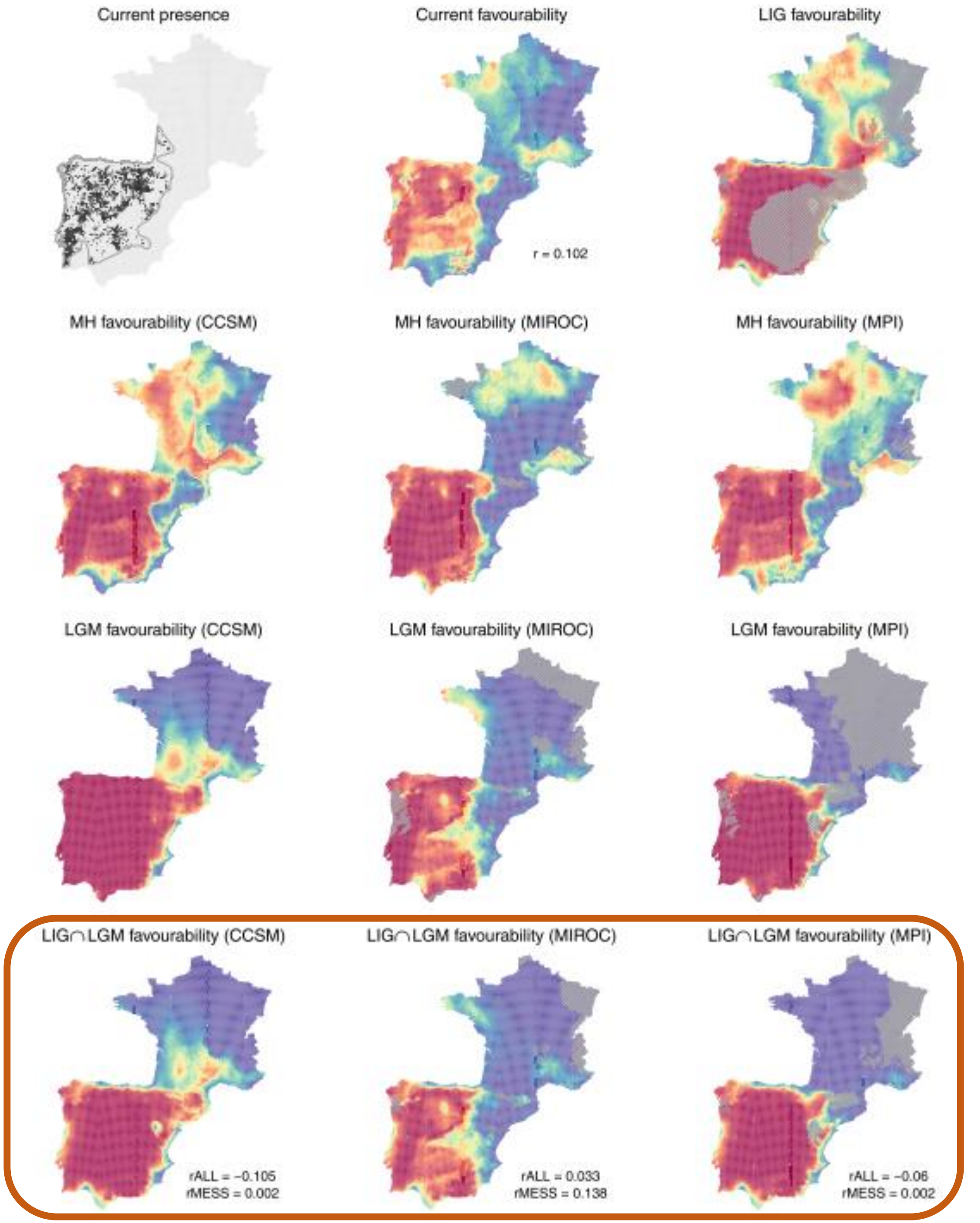
RESEARCH ARTICLE

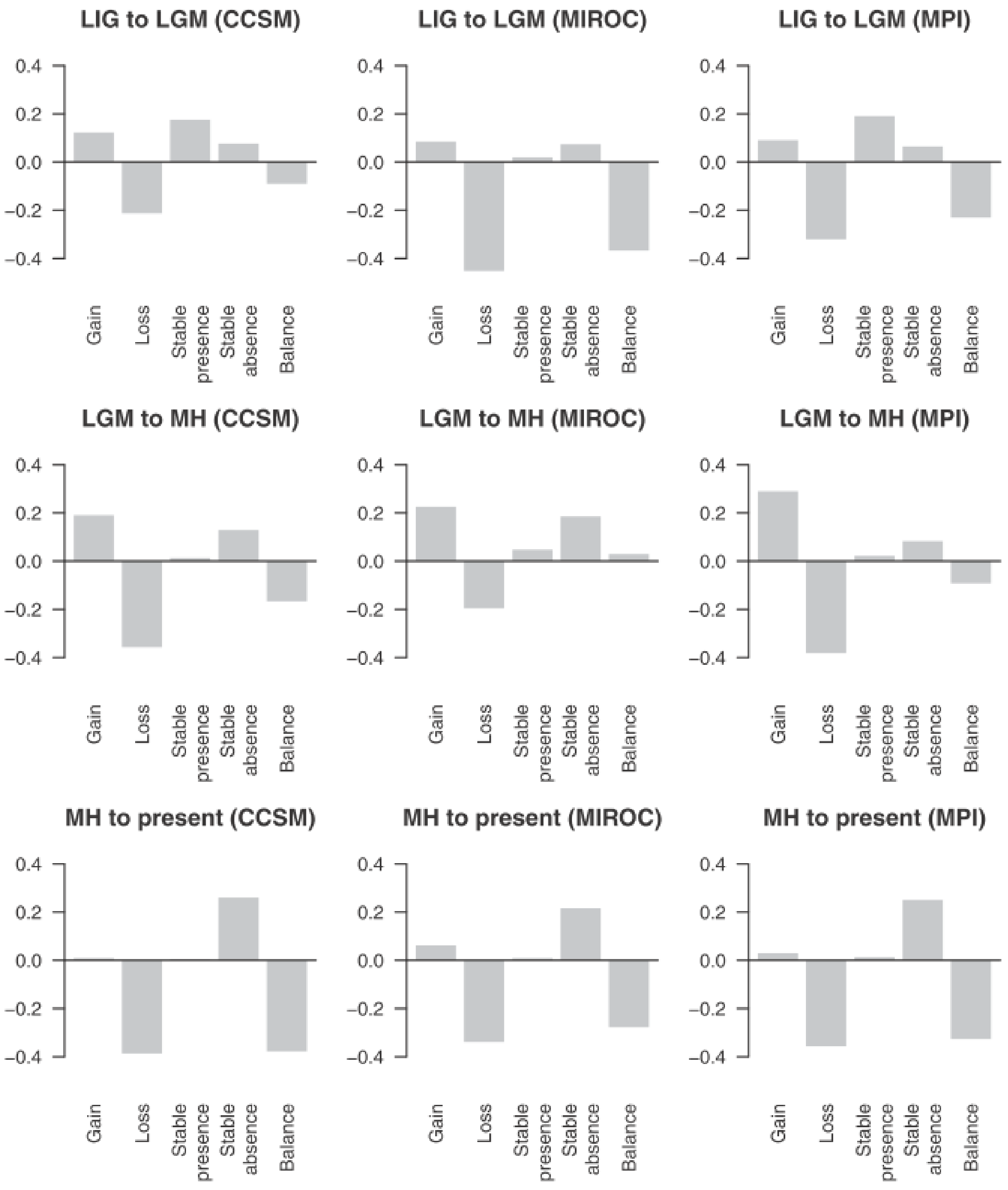
WILEY Journal of Biogeography

Complementing the Pleistocene biogeography of European amphibians: Testimony from a southern Atlantic species

Gregorio Sánchez-Montes[1] | Ernesto Recuero[2] | A. Márcia Barbosa[3] |
Íñigo Martínez-Solano[1,2,4]

Current occurrence and climatic **favourability** in the present and under projected climates for the Last Inter-Glacial (LIG) and for each of three simulations for the Last Glacial Maximum (LGM) and the Mid Holocene (MH).



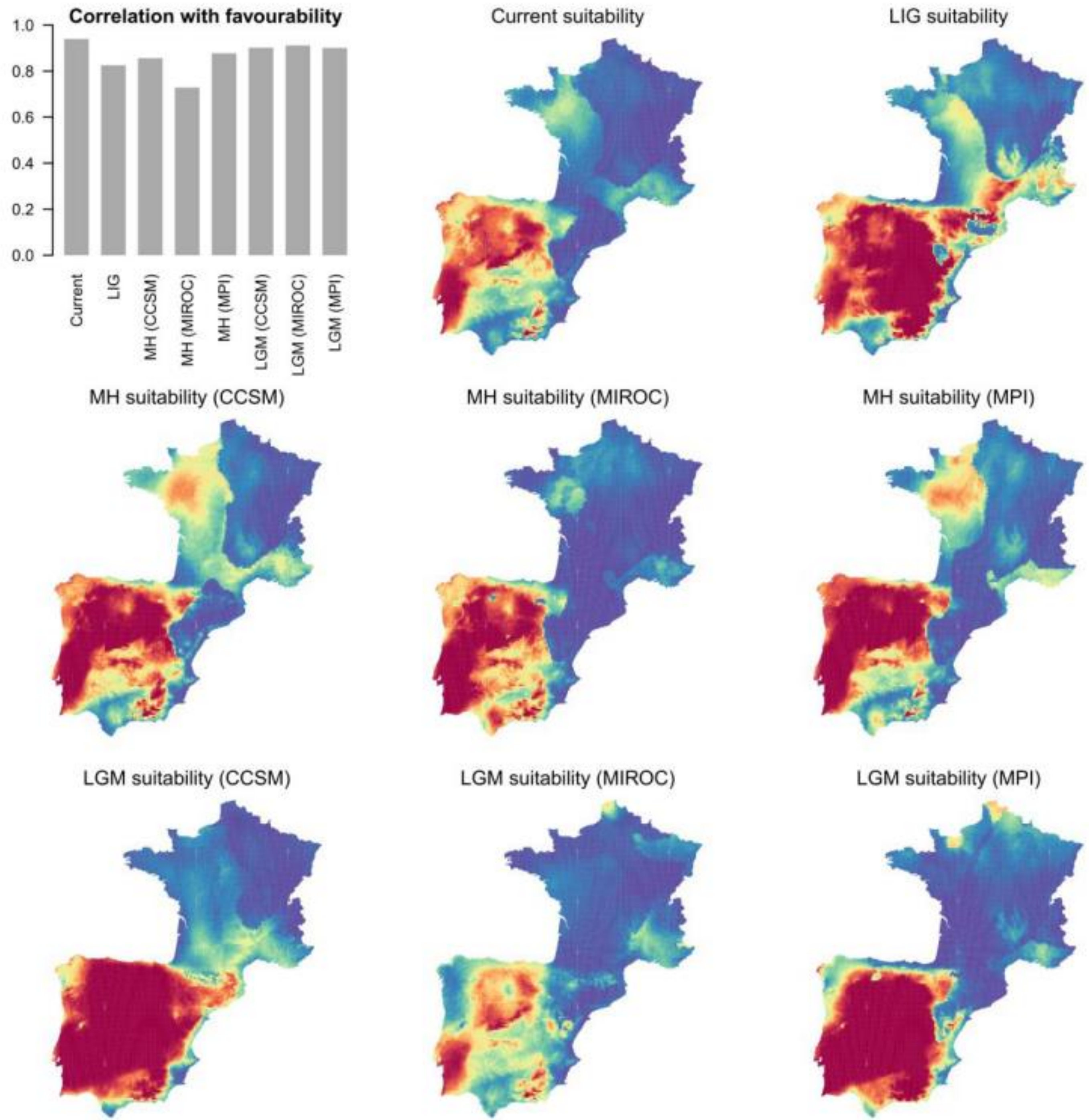


Fuzzy range change measures (fuzzy equivalents of the proportional gain, loss and overall change in climatically favourable areas) among time periods, from the Last Inter-Glacial (LIG) to the LGM, the Mid Holocene (MH) and the present, including the three paleoclimatic simulations.

[...]

taxa and time periods (Acevedo & Real, 2012). Unlike the generality of other algorithms, which model probability or suitability, favourability can be formally used in fuzzy logical analyses (Acevedo & Real, 2012; Real et al., 2006), such as the intersections that assess the maintenance of adequate conditions across time periods (see below). Nevertheless, to ensure that the choice of modelling approach did not strongly affect our conclusions, we also modelled the same data with the widely used algorithm Maxent. We built this model with the MAXNET R package, using linear and quadratic features (Merow, Smith, & Silander, 2013) and a complementary log–log (cloglog) transform (Phillips, Anderson, Dudík, Schapire, & Blair, 2017). We then mapped these predictions for each climate scenario and measured their correlations with the corresponding favourability predictions.

Maxent predictions: highly correlated with (not *better* or *worse* than) GLM predictions, but not directly comparable or appropriate for fuzzy logic



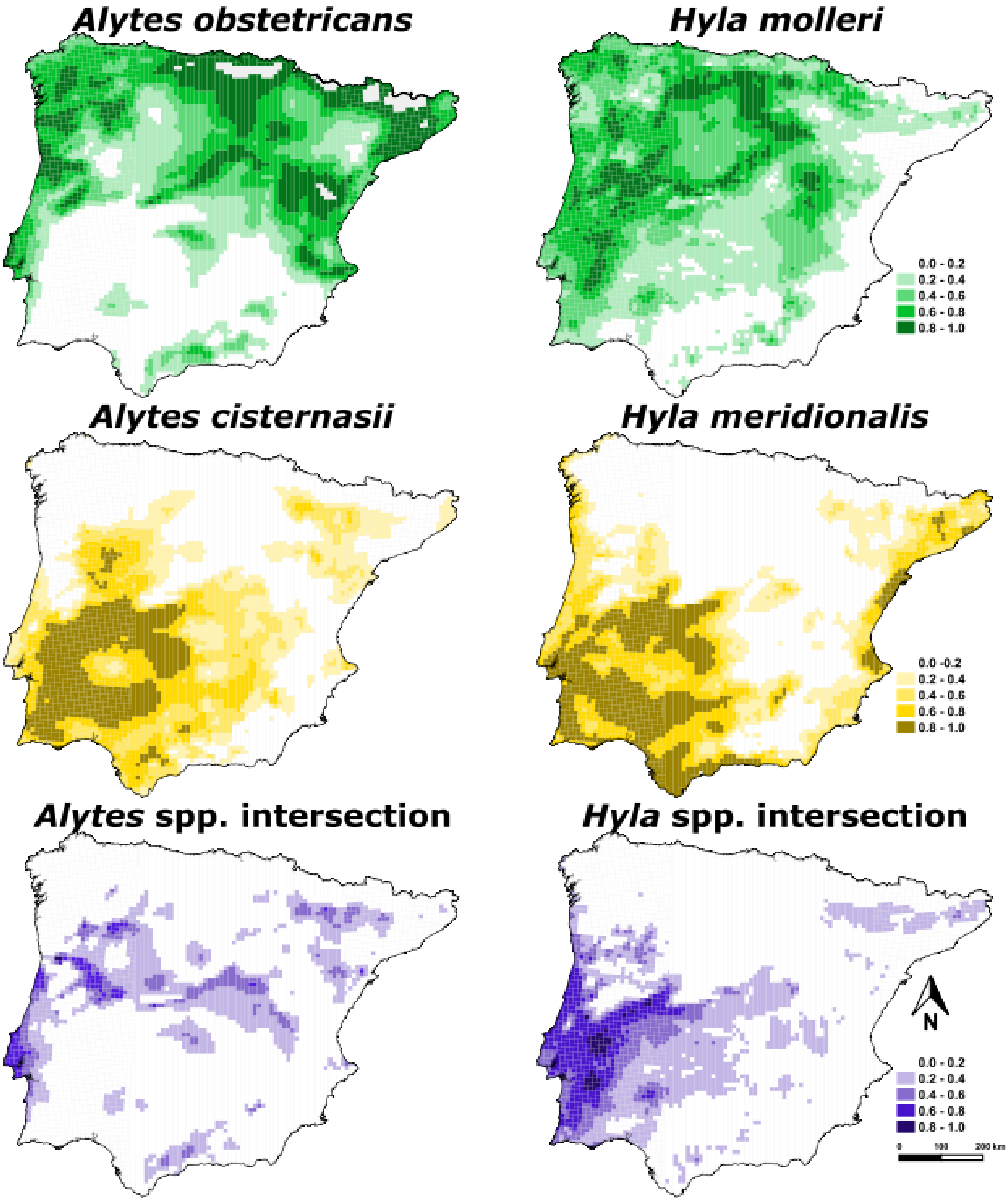
Case study

Journal of Biogeography (*J. Biogeogr.*) (2017) **44**, 88–98

ORIGINAL ARTICLE

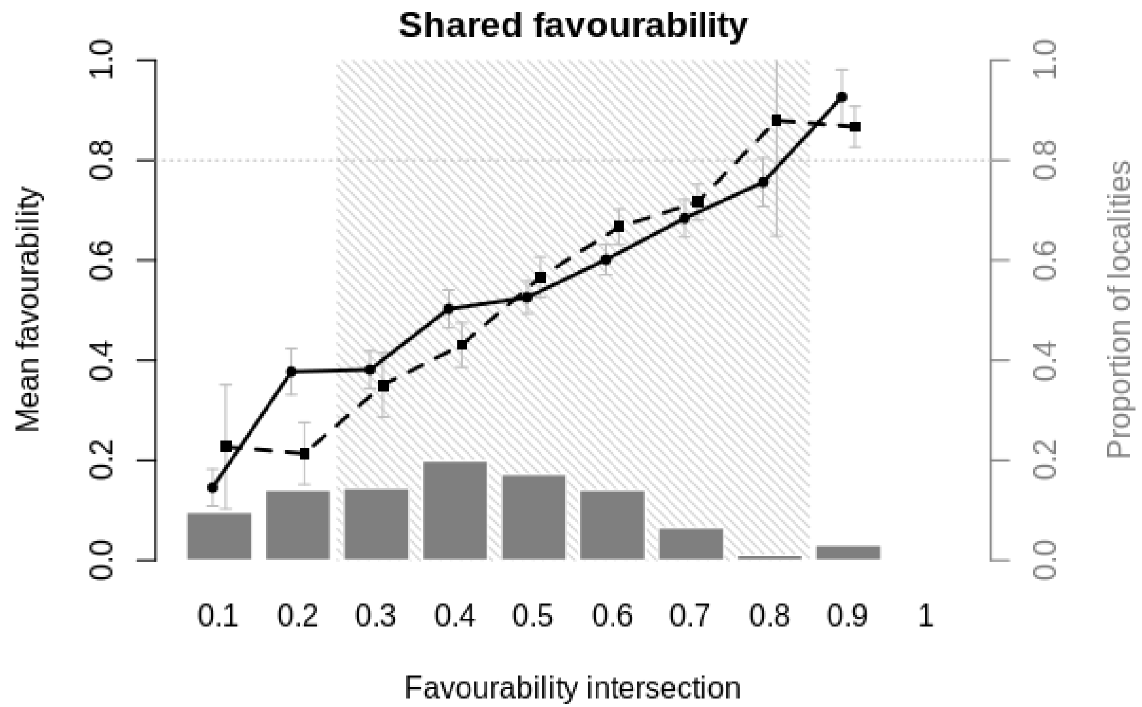
Favourable areas for co-occurrence of parapatric species: niche conservatism and niche divergence in Iberian tree frogs and midwife toads

Luís Reino[1,2,3#], Mário Ferreira[1,3#], Íñigo Martínez-Solano[1,4], Pedro Segurado[5], Chi Xu[6] and A. Márcia Barbosa[2*]



Environmental favourability values for the studied species and their fuzzy intersection (favourability for co-occurrence) within each congeneric pair.

Shared favourability for interacting species



Diversity and Distributions, (Diversity Distrib.) (2010) **16**, 515–528

BIODIVERSITY RESEARCH

Assessing biogeographical relationships of ecologically related species using favourability functions: a case study on British deer

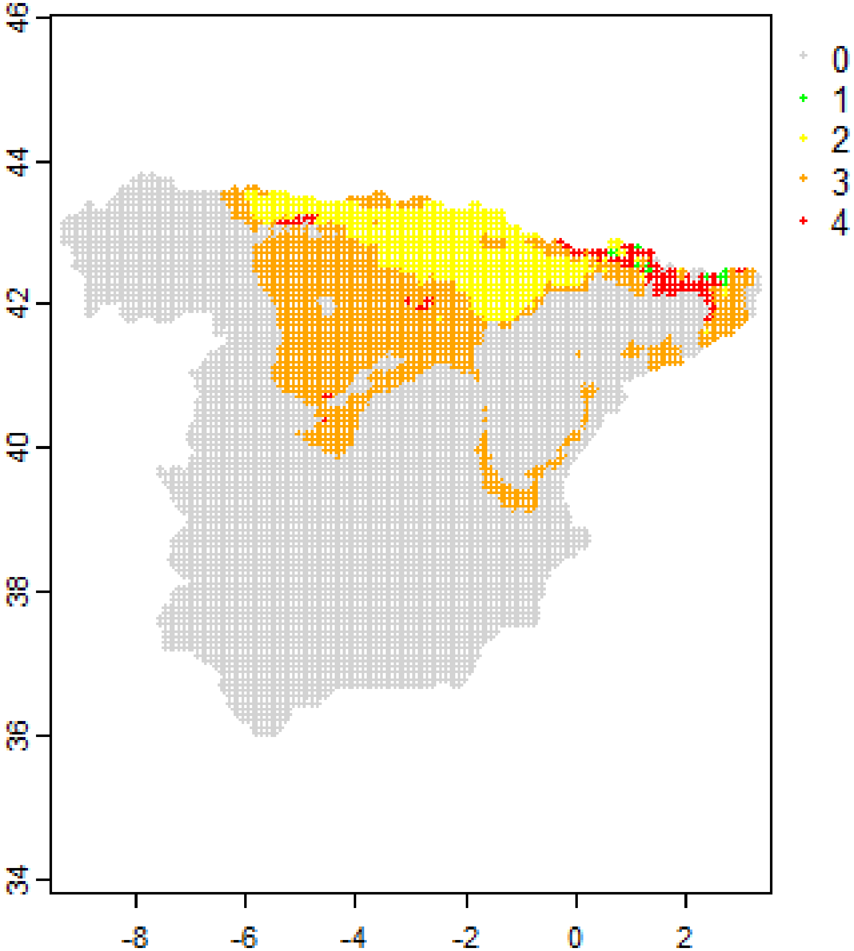
Pelayo Acevedo[1,2,3]*, Alastair I. Ward[2], Raimundo Real[1] and Graham C. Smith[2]

Global Change Biology (2012), doi: 10.1111/j.1365-2486.2012.02655.x

Parapatric species and the implications for climate change studies: a case study on hares in Europe

PELAYO ACEVEDO*†‡, ALBERTO JIMÉNEZ-VALVERDE*, JOSÉ MELO-FERREIRA†, RAIMUNDO REAL* and PAULO CÉLIO ALVES†§¶

Biotic threat among interacting species



0 (grey): abiotic (no biotic threat)

1 (green): sympatric coexistence

2 (yellow): moderate biotic threat

3 (orange): high biotic threat

4 (red): very high biotic threat

See `?bioThreat` for detailed explanation!

PRACTICAL

```
# crisp and fuzzy similarity between two species:

with(dat, fuzSim(Lutrlutr, Neovviso, method =
"Jaccard"))

with(dat, fuzSim(Lutrlutr_F, Neovviso_F, method =
"Jaccard"))


# crisp and fuzzy similarity among several species:

bin_sim_mat <- simMat(dat[ , spp_cols], method =
"Jaccard")

fuz_sim_mat <- simMat(dat[ , fav_cols], method =
"Jaccard")
```

PRACTICAL

```
# fuzzy range change between present and future:
fuzzyRangeChange(dat[ , "Muslut_F"], dat_fut[ ,
"Muslut_F_fut"])


# shared favourability among two interacting species:
with(dat, sharedFav(Neovis_F, Muslut_F))


# biotic threat among two interacting species:
dat$threat_NvMl <- with(dat, bioThreat(Neovis_F,
Muslut_F))
```