Analyse spatiale multi-échelles de données écologiques avec adespatial

Stéphane Dray

Rencontres R - 2017

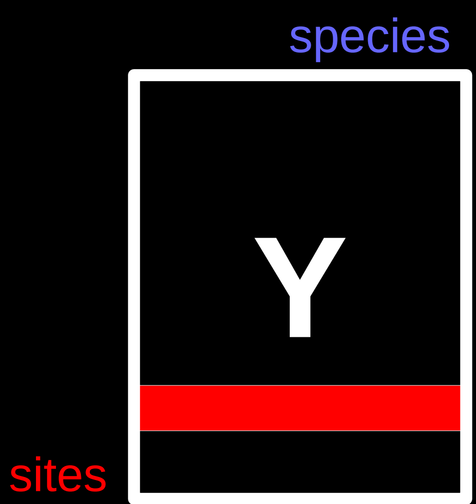
Ecological communities

Gewin V (2006) PLoS Biology

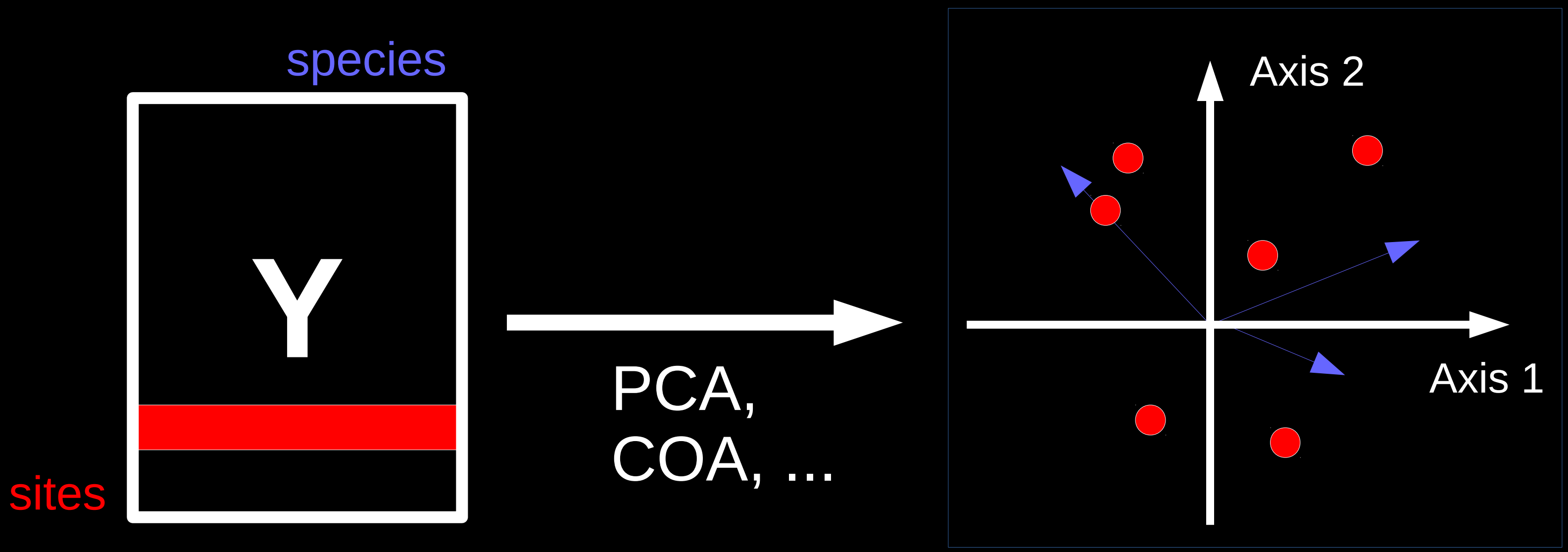
Community ecology

- Describe communities (species assemblages)
- Study how their composition vary (in space or time)
- Identify factors/processes behind these patterns

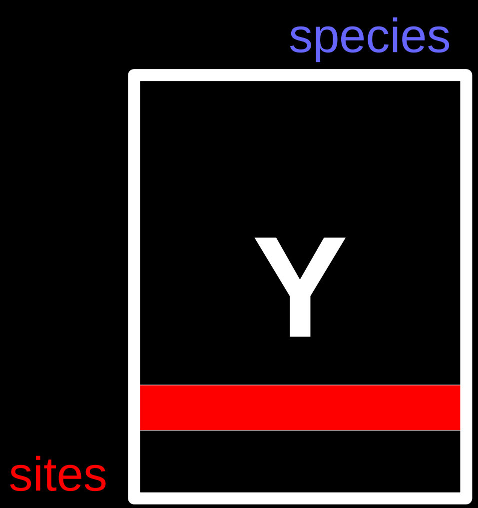
One-table ordination

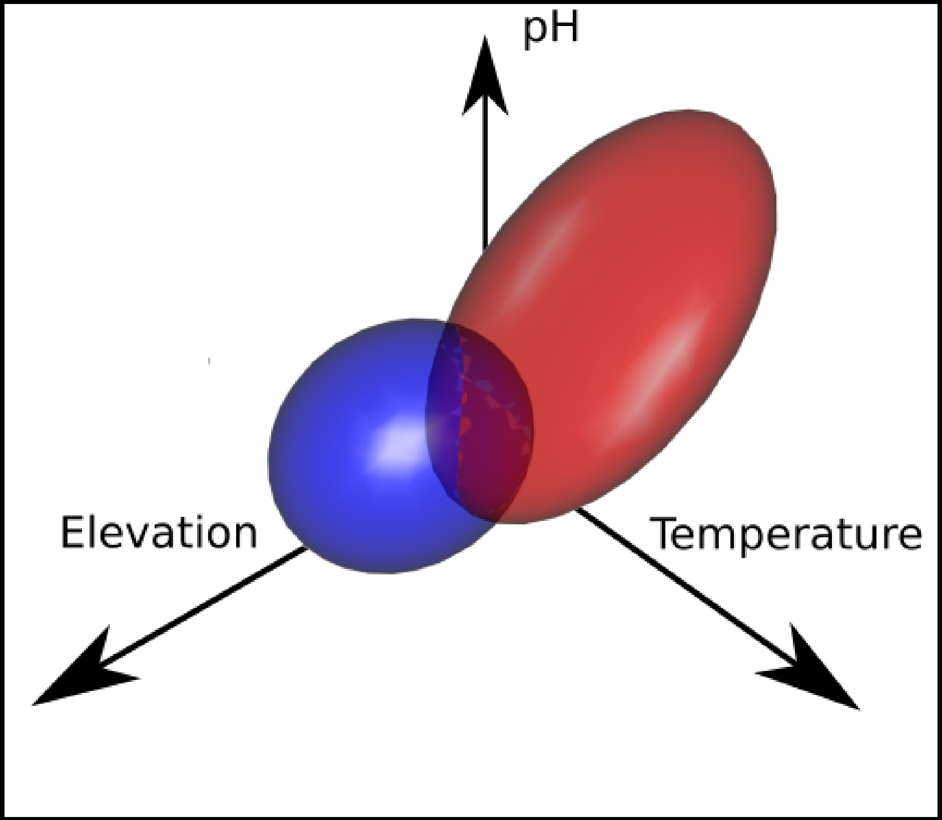


One-table ordination



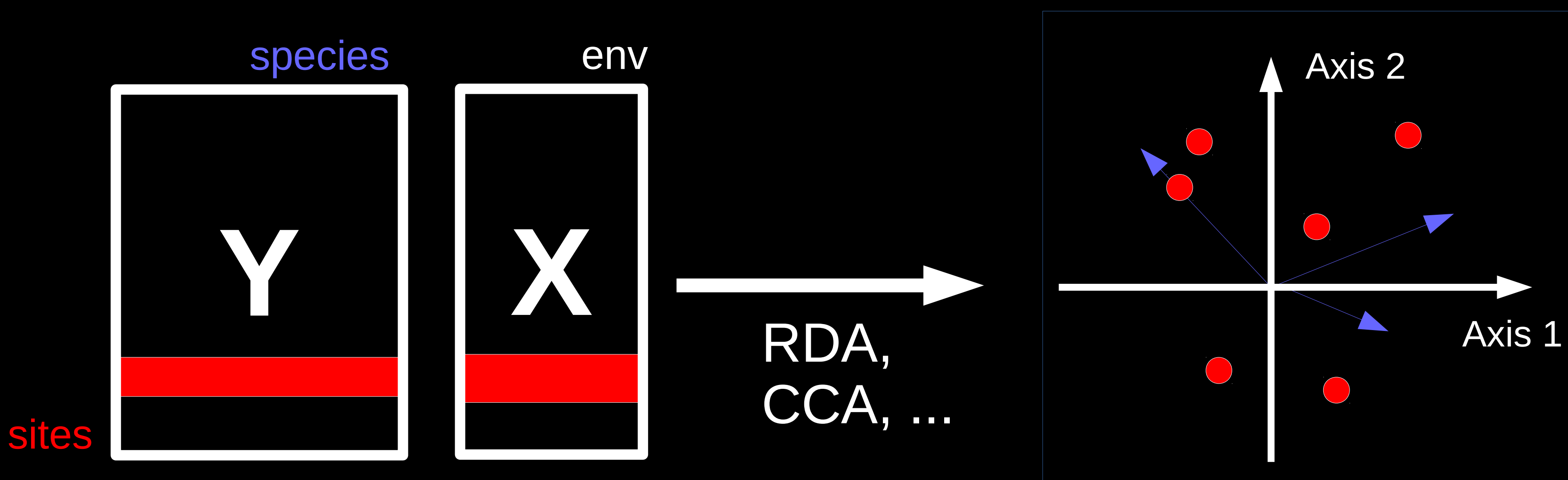
The niche theory





Hutchinson (1957) Population studies: animal ecology and demography

Two-tables ordination



Environmental constraint

Axis = f(**X**)=$a_1\mathbf{x}_1+a_2\mathbf{x}_2+\ldots+a_P\mathbf{x}_p$

ter Braak (1986) Ecology ; ter Braak (1987) Vegetatio

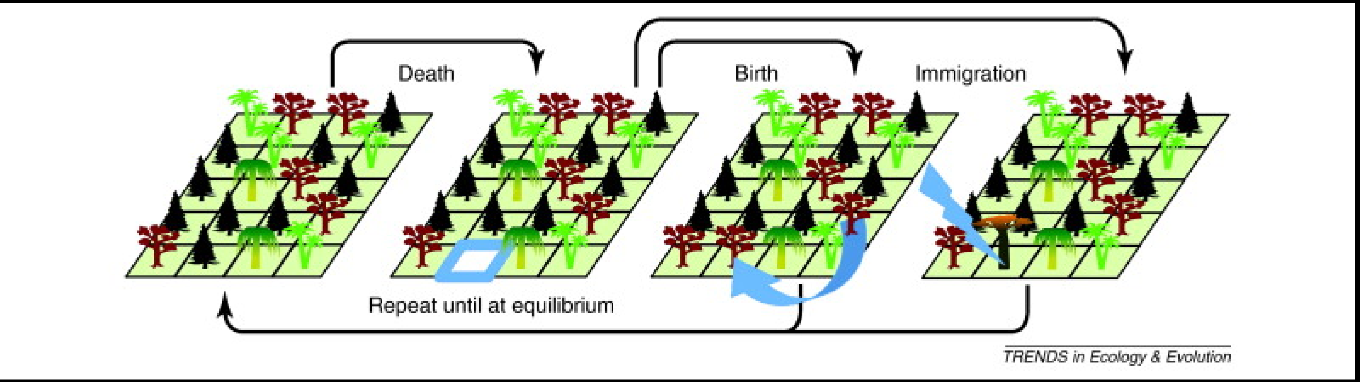
Spatial patterns as proxies

- Some missing environmental variables
- Other ecological processes could act

Spatial patterns as proxies

- Some missing environmental variables
- Other ecological processes could act

Species are equivalent, only stochastic events



Hubbell (2001)

Rosindell et al. (2011) TREE

Spatial patterns as proxies

- Some missing environmental variables
- Other ecological processes could act
- Spatial structures as proxies of unmeasured variables / unknown processes

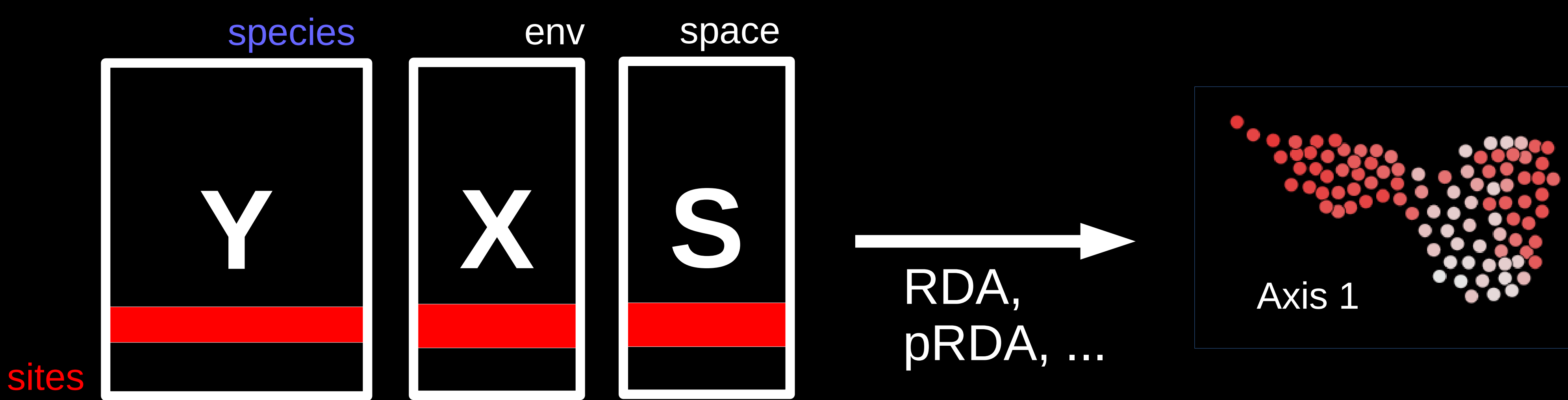
Ecology, 90(1), 2009, pp. 46–56

Beyond description: the active and effective way to infer processes from spatial patterns

ELIOT J. B. MCINTIRE[1,4] AND ALEX FAJARDO[2,3]

McIntire & Fajardo (2009) Ecology

Spatial patterns



- Spatial patterns linked to environment (Y~X ↔ S)
- Spatial patterns due to other factors (Y|X ↔ S)
- Which scales?

How integrate spatial information?

- Mapping (Goodall, 1954)
- Spatial weights (Moran, 1954)
- Spatial predictors:
  - Polynomials (Gittins, 1968)
  - PCNM (Borcard & Legendre, 2002)
  - MEM (Dray et al, 2006)
  - AEM (Blanchet et al, 2008)

How integrate spatial information?

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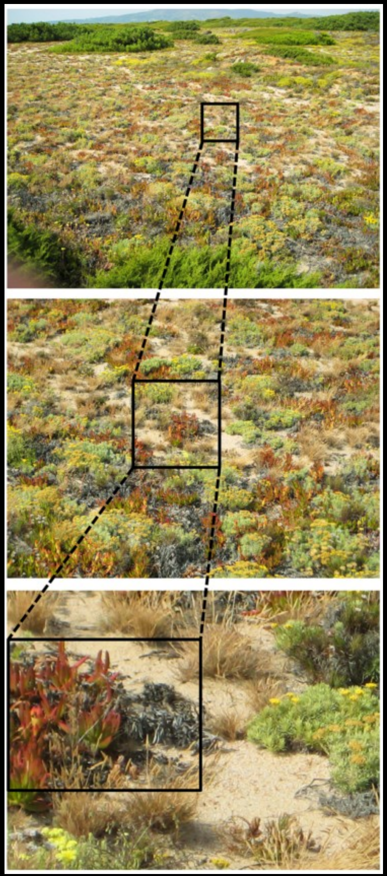


- Table: sites x variables
- Variables = scales
- Orthonormal predictors

2008

SEDAR

[redacted]patial Ecological Data Analysis with R" Workshop

2012

REVIEWS

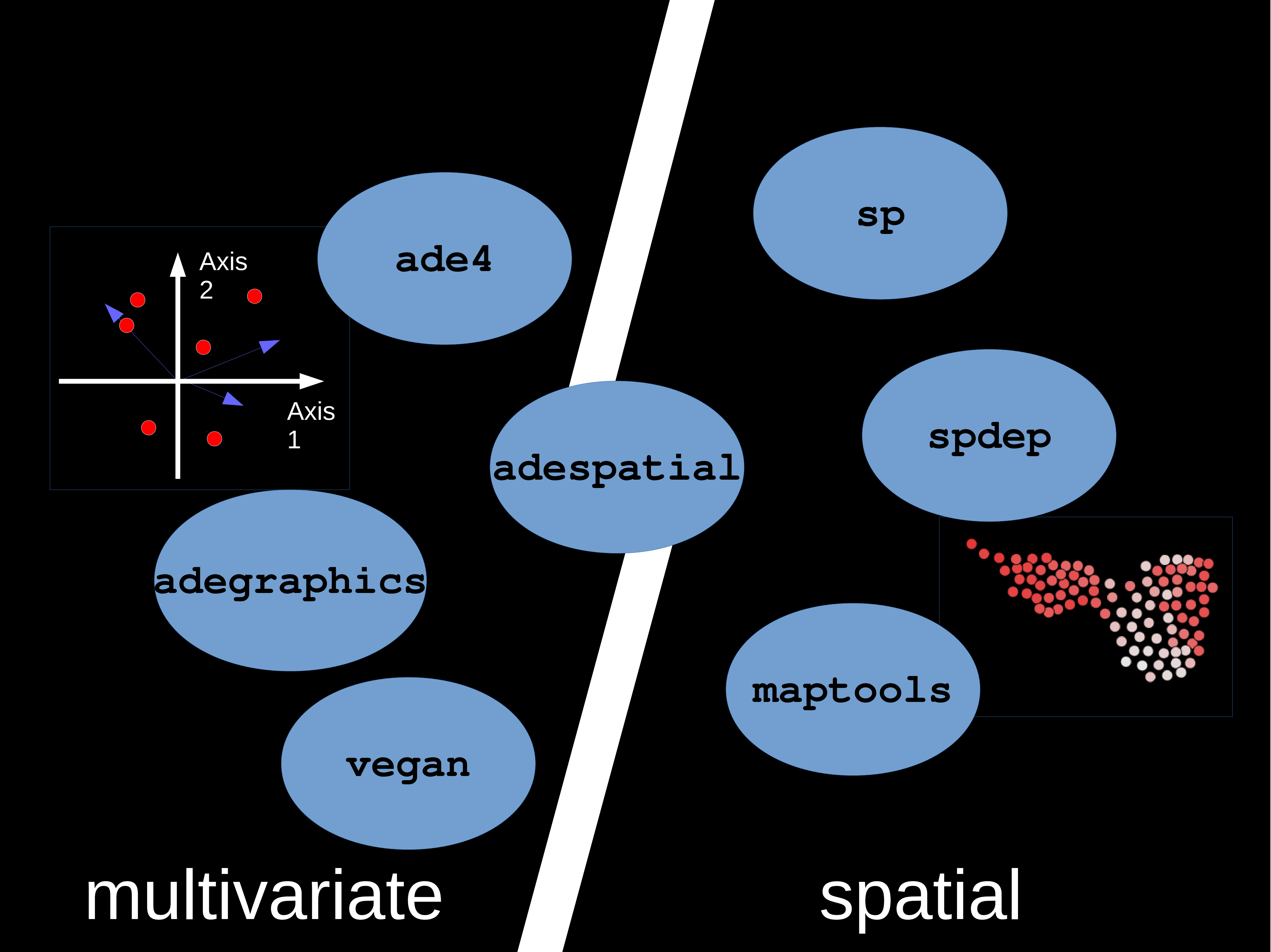
[redacted] *Monographs*, 82(3), 2012, pp. 257–275

Community ecology in the age of multivariate multiscale spatial analysis

S. Dray,[1,16] R. Pélissier,[2,3] P. Couteron,[2] M.-J. Fortin,[4] P. Legendre,[5] P. R. Peres-Neto,[6] E. Bellier,[7,8] R. Bivand,[9] F. G. Blanchet,[10] M. De Cáceres,[11] A.-B. Dufour,[1] E. Heegaard,[12] T. Jombart,[1,13] F. Munoz,[2] J. Oksanen,[14] J. Thioulouse,[1] and H. H. Wagner[15]

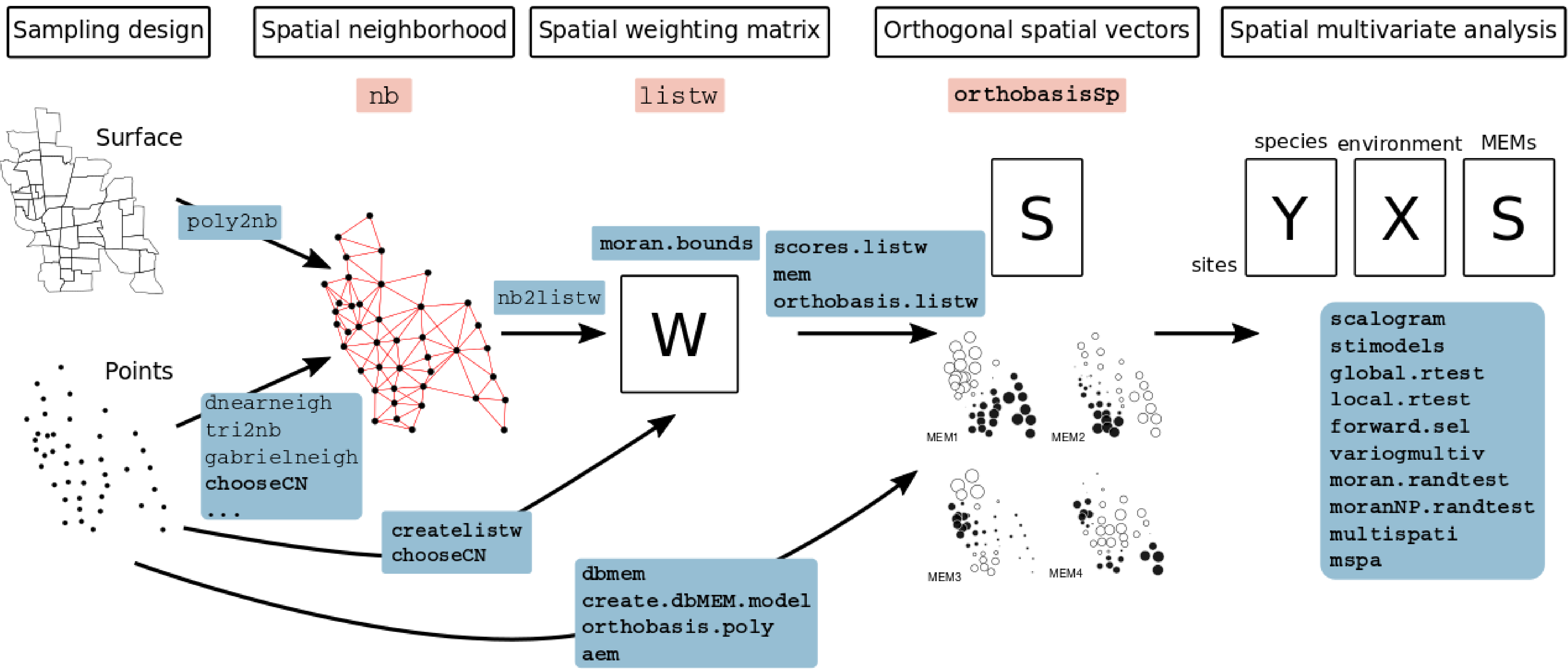
2015

`adespatial` 0.0-1 on CRAN

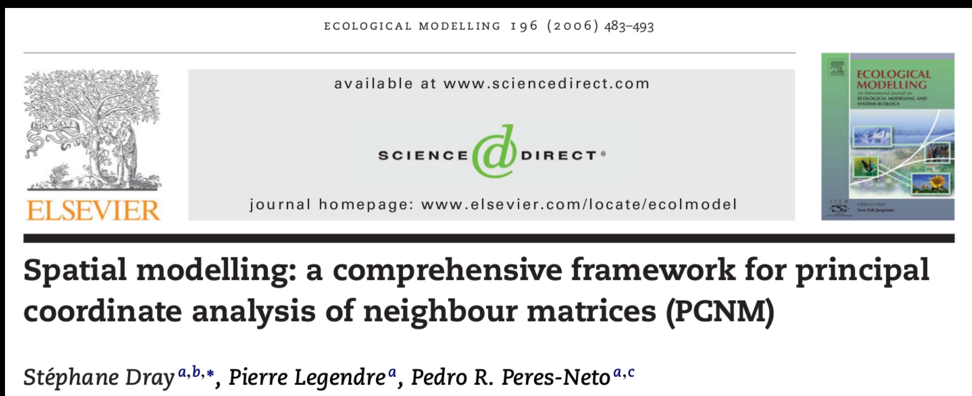


ade4
Axis 2
Axis 1
adespatial
adegraphics
vegan
sp
spdep
maptools
multivariate
spatial

adespatial: an overview



Space as a graph (spatial weights matrix)



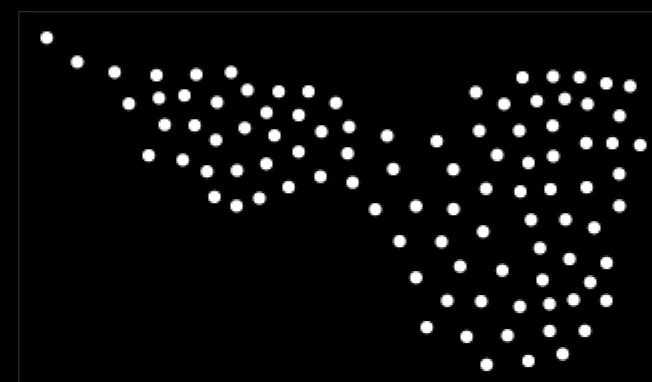
ECOLOGICAL MODELLING 196 (2006) 483–493

available at www.sciencedirect.com

journal homepage: www.elsevier.com/locate/ecolmodel

Spatial modelling: a comprehensive framework for principal coordinate analysis of neighbour matrices (PCNM)

Stéphane Dray[a,b,*], *Pierre Legendre*[a], *Pedro R. Peres-Neto*[a,c]



Dray et al (2006) Ecological Modelling

Space as a graph (spatial weights matrix)

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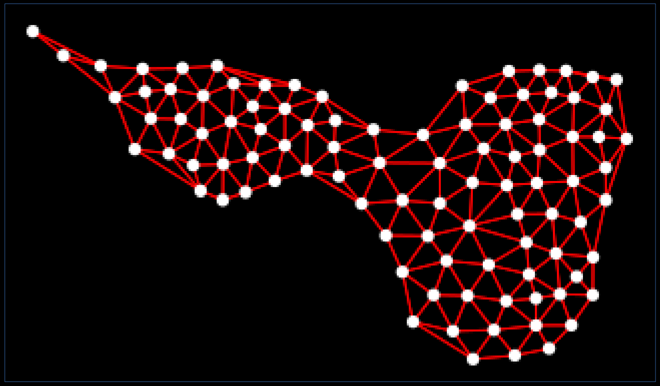

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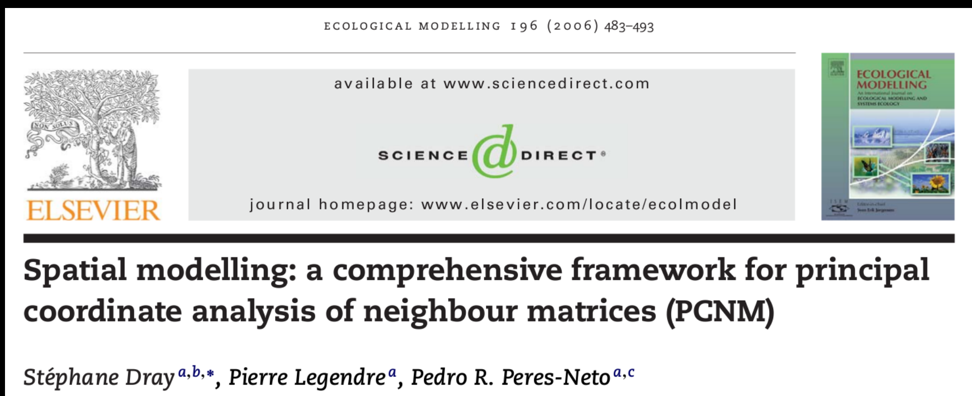

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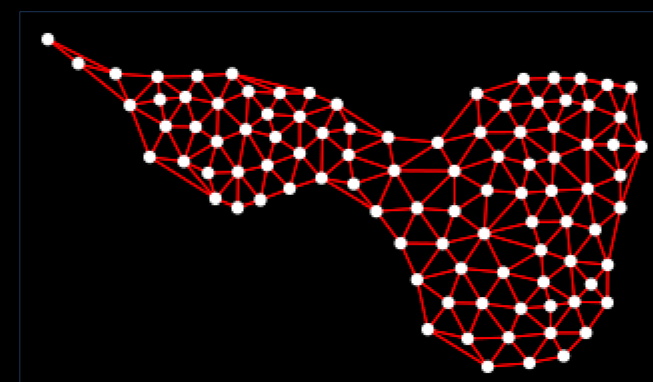
ECOLOGICAL MODELLING

Spatial modelling: a comprehensive framework for principal coordinate analysis of neighbour matrices (PCNM)

Stéphane Dray[a,b,*], *Pierre Legendre*[a], *Pedro R. Peres-Neto*[a,c]

$$\mathbf{W} = \begin{bmatrix} 0 & 1 & \cdots & 0 \\ 1 & 0 & \cdots & 1 \\ \vdots & \vdots & \cdots & \vdots \\ 0 & 1 & \cdots & 0 \end{bmatrix}$$



Dray et al (2006) Ecological Modelling

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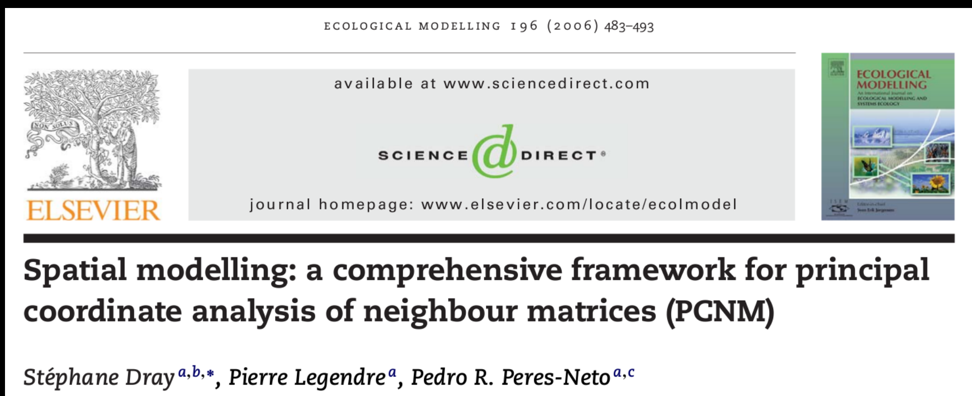
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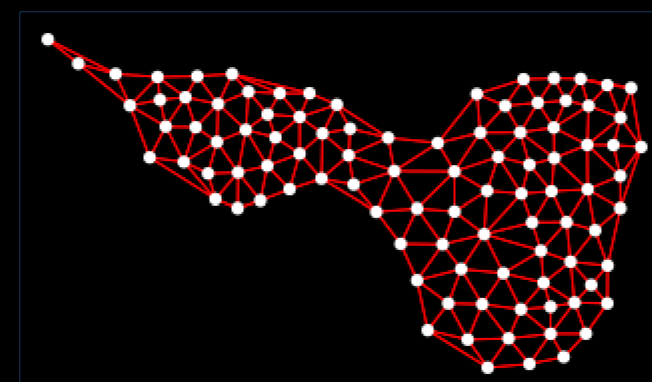
Spatial modelling: a comprehensive framework for principal coordinate analysis of neighbour matrices (PCNM)

Stéphane Dray[a,b,], Pierre Legendre[a], Pedro R. Peres-Neto[a,c]*

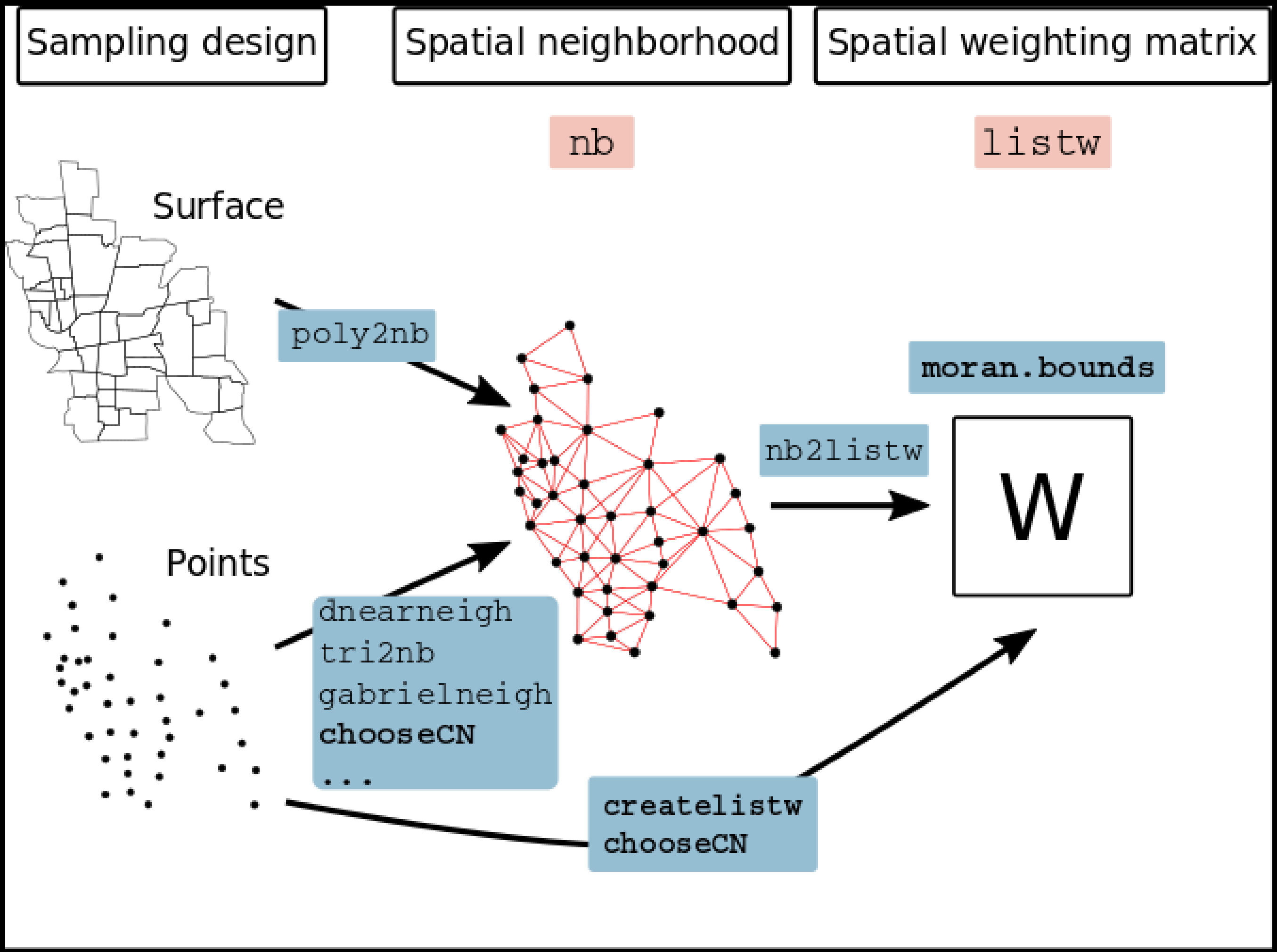


$$\mathbf{W} = \begin{bmatrix} 0 & 1 & \cdots & 0 \\ 1 & 0 & \cdots & 1 \\ \vdots & \vdots & \cdots & \vdots \\ 0 & 1 & \cdots & 0 \end{bmatrix}$$

$$MC(\mathbf{x}) = \frac{n}{\mathbf{1}_n^\top \mathbf{W} \mathbf{1}_n} \frac{\mathbf{x}^\top \mathbf{HWHz}}{\mathbf{z}^\top \mathbf{HHz}} = \frac{n \sum_{i,j} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i,j} w_{ij} \sum_i (x_i - \bar{x})^2}$$

Dray et al (2006) Ecological Modelling

From spatial sampling to weights



createlistw

Generate R code to create a spatial weighting matrix

nb options

Sp object or coordinates:

xyir

Graph type:

Gabriel

- Delaunay
- Gabriel
- Relative
- Minimum spanning tree
- Distance
- K-nearest

listw options

Standardization style:

W

General weights:

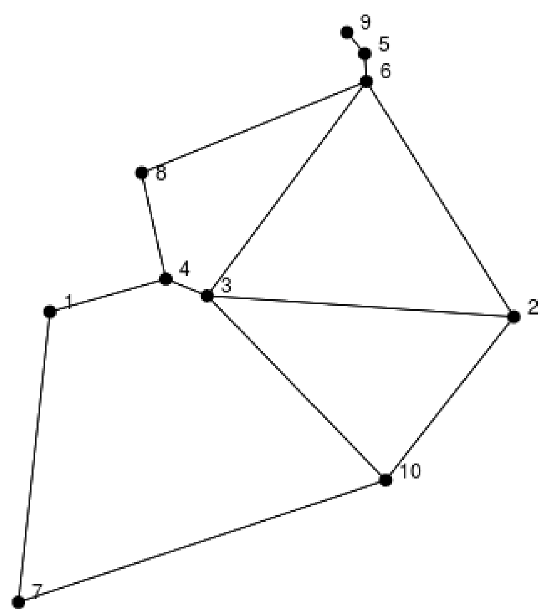
1 - d/max(d)

R code (copy & paste in the R console):

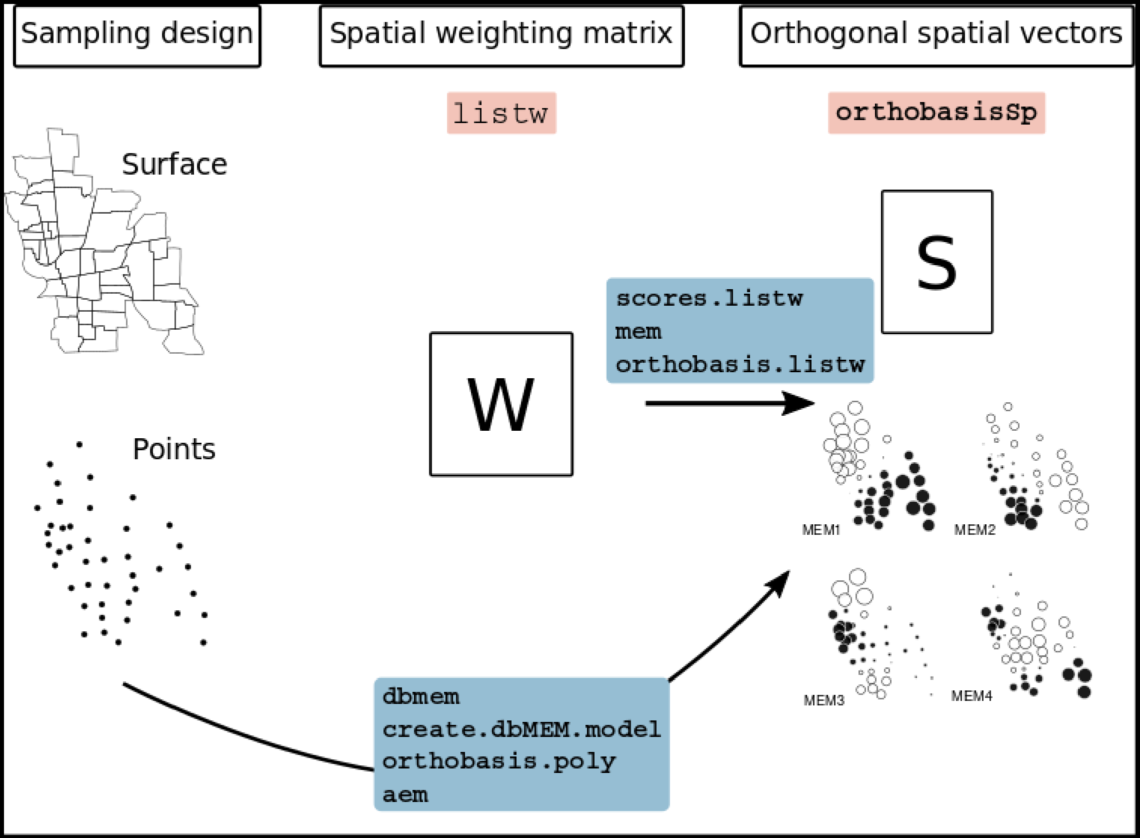
```
library(adespatial);library(sp);library(spdep);
nb <- chooseCN(coordinates(xyir), type = 2, plot.nb = FALSE)
distnb <- nbdists(nb, xyir)
fdist <- lapply(distnb, function(x) 1 - x/max(dist(xyir)))
lw <- nb2listw(nb, style = 'W', glist = fdist, zero.policy = TRUE)
```

Display summary

no yes



From weights to spatial predictors



`orthobasisSp`

- **`plot`, `summary`, `print`** methods
- inherits from **`data.frame`**

Moran's Eigenvector Maps

$$\mathbf{HWHV} = \mathbf{V\Lambda}$$

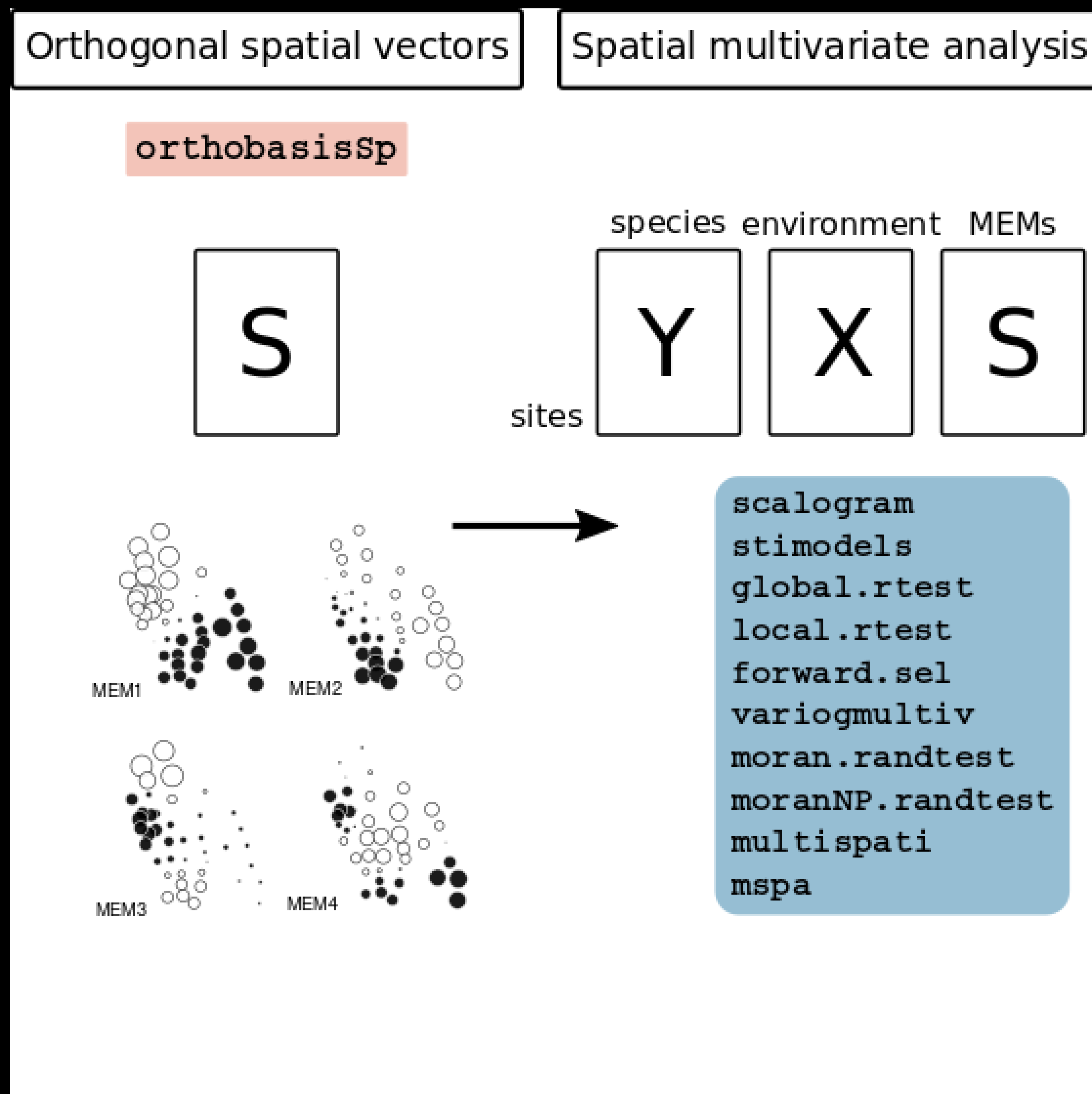
Eigenvectors are orthogonal and maximize Moran’s coefficient :

$$MC(\mathbf{v}_i) = \lambda_i$$

```
mymem <- mem(mylistw)
plot(mymem[,c(1,2,10,69], xy)
```

Dray et al (2006) Ecological Modelling

Spatial multiscale/multivariate methods



Univariate multiscale methods

- Moran's Index: `moran.randtest(x, mylistw)`

- Positive/Negative decomposition: `moranNP.randtest(x, mylistw)`

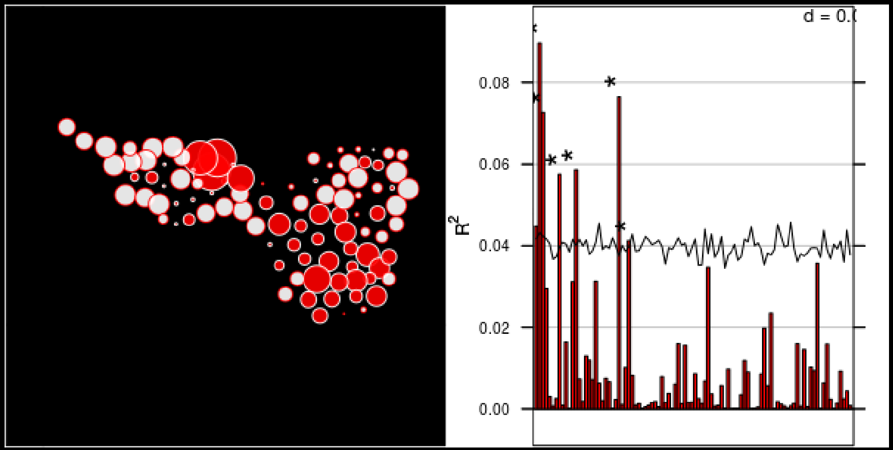
$$MC(\mathbf{x}) = \sum_{i=1}^{n-1} \lambda_i cor^2(\mathbf{x}, \mathbf{v}_i)$$

Dray (2011) Geographical Analysis

- Multiscale decomposition:

```
scalogram(x, mymem)
mspa(mypca, mymem)
```

$$\sum_{i=1}^{n-1} cor^2(\mathbf{x}, \mathbf{v}_i) = 1$$



Dray et al (2012) Ecological Monographs

Jombart, Dufour & Dray (2009) Ecography

Spatial multivariate methods

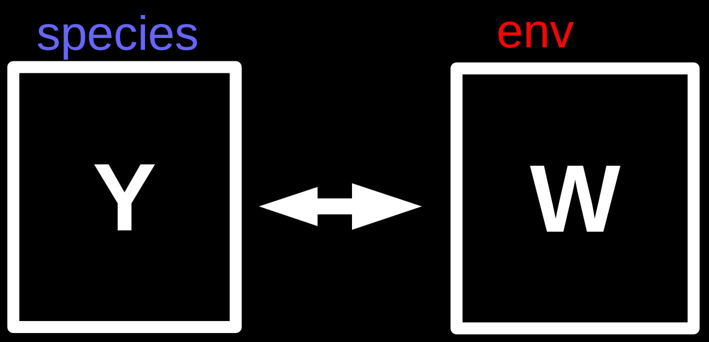
- Multivariate autocorrelation: `global.rtest(Y, mylistw)`

  Jombart et al (2008) Heredity

- Spatial multivariate analysis:

  ```
  multispati(mypca, mylistw)
  ```

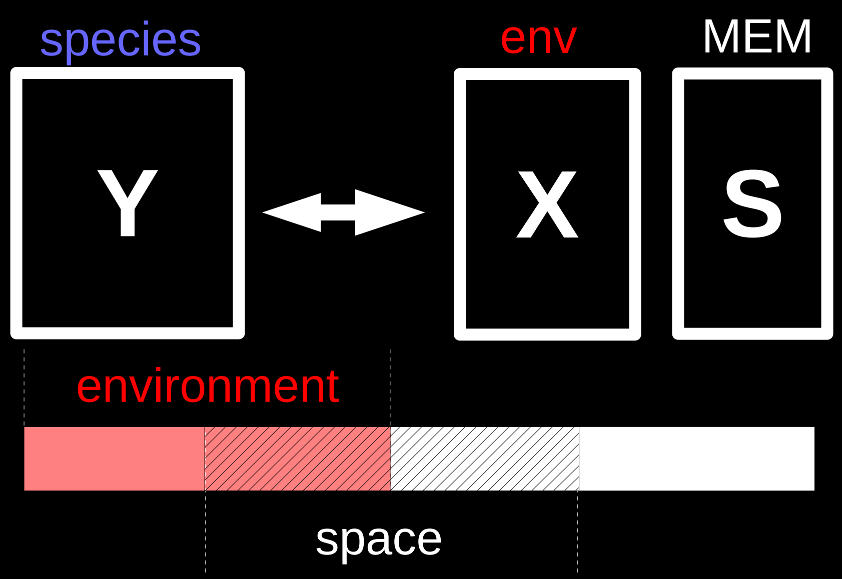
  Dray et al (2008) Journal of Vegetation Science



- Constrained ordination/Variation partitioning:

  ```
  pcaiv(mypca, mymem)
  varpart(Y, X, mymem)
  ```

  Dray et al (2012) Ecological Monographs



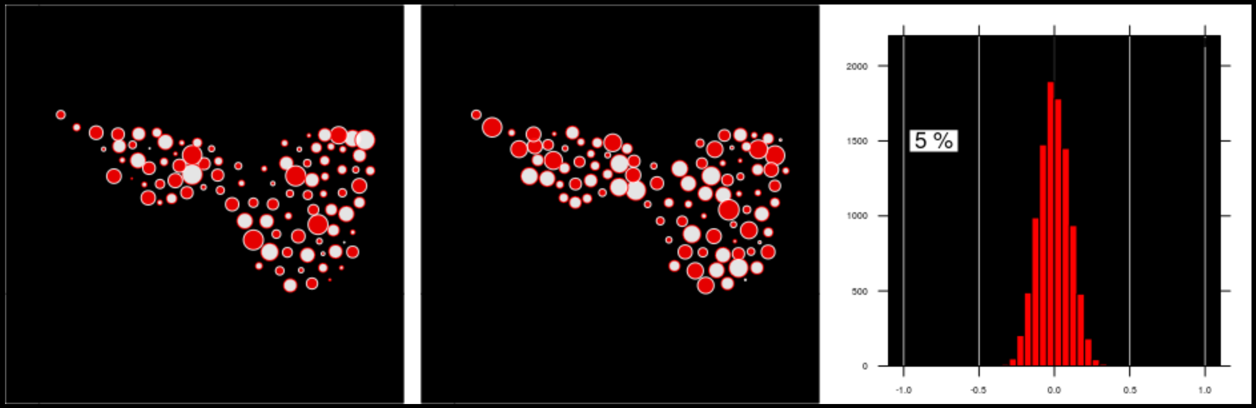
The two faces of spatial autocorrelation

Proxies for unmeasured processes

Non-independent observations

Inference and spatial autocorrelation

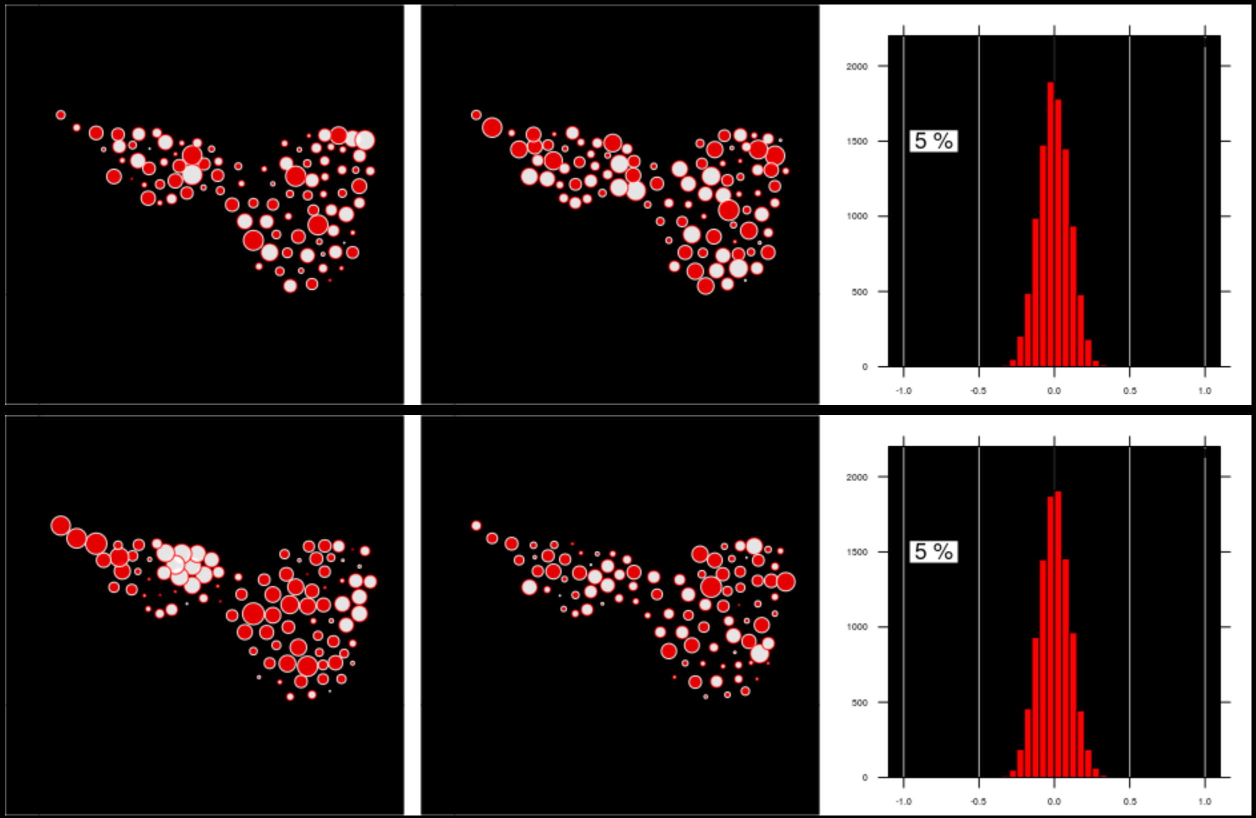
- No spatial structure



Inference and spatial autocorrelation

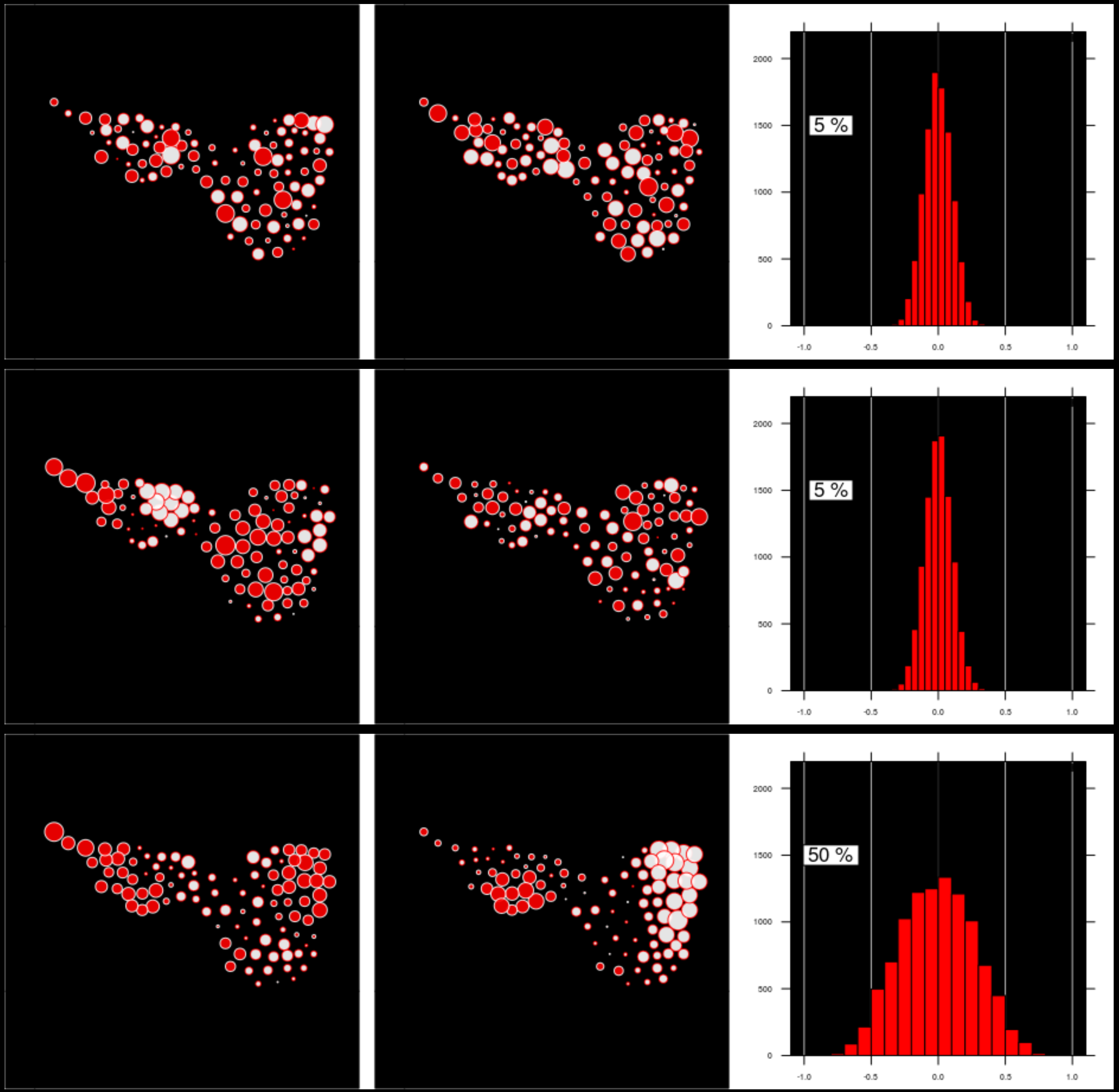
- No spatial structure

- One spatial structure



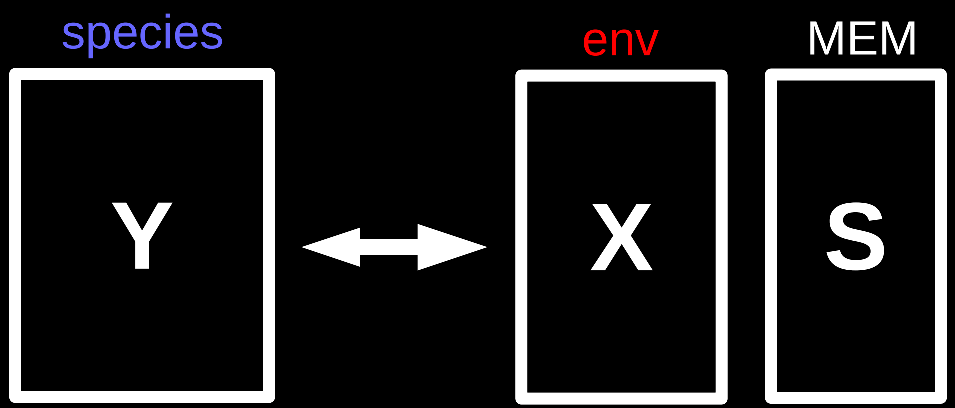
Inference and spatial autocorrelation

- No spatial structure
- One spatial structure
- Two independent spatial structures



Consequences in ordination

- **X** and **Y** independents
  X and **Y** spatially structured



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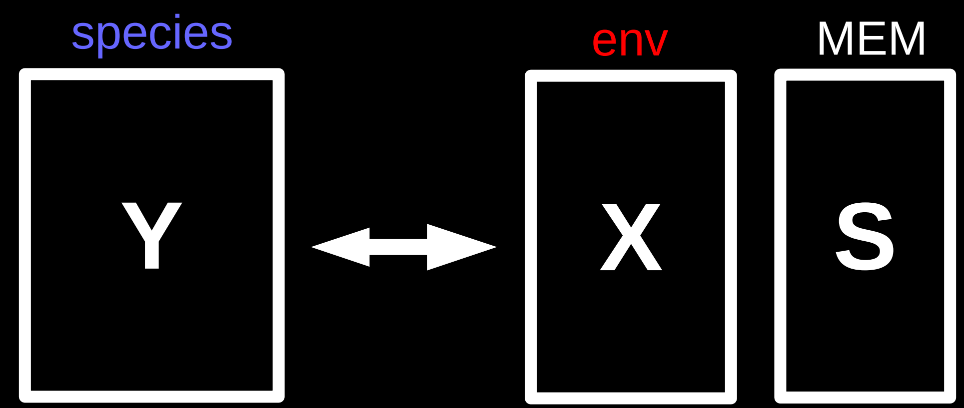
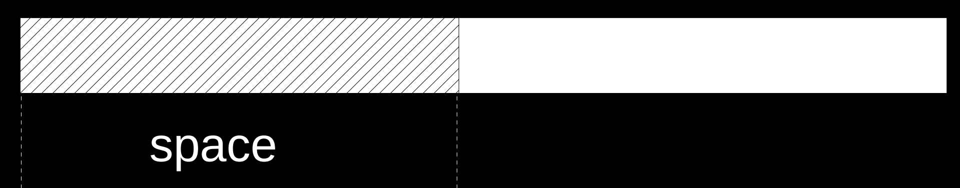


- In theory



Consequences in ordination

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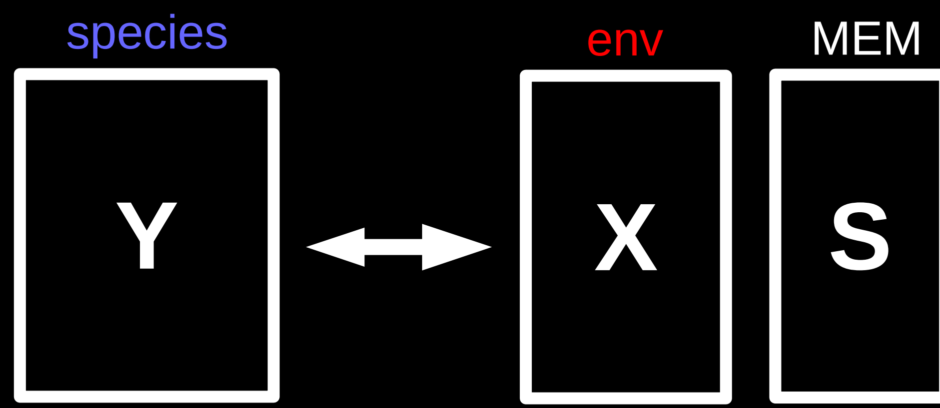

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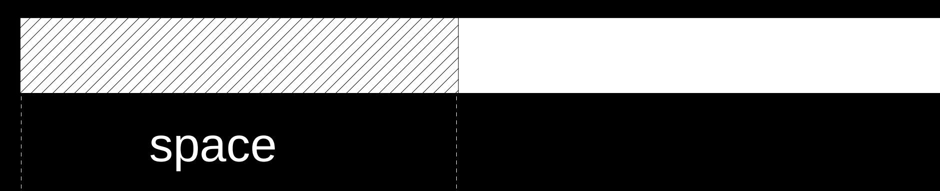
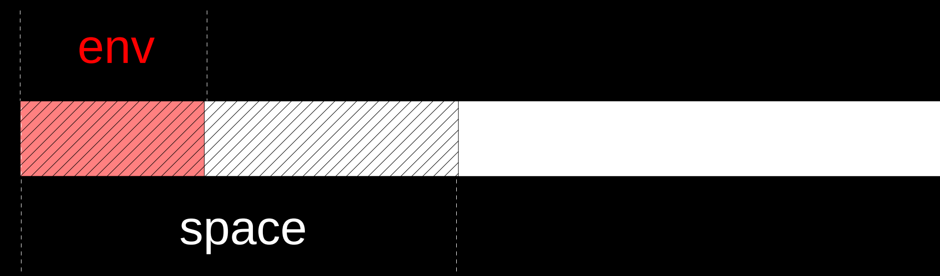
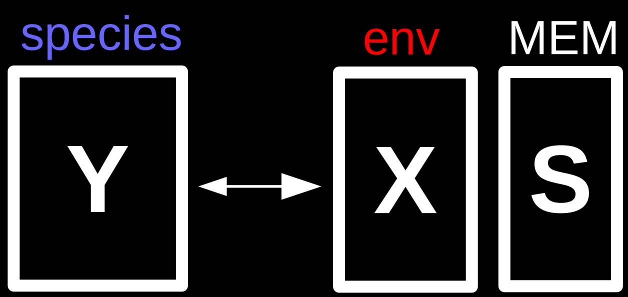


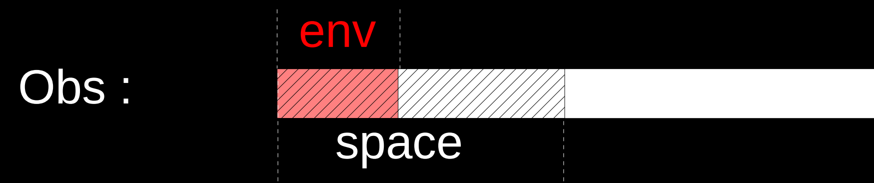
- In practice



Constrained null models

- Observed data





Clappe et al (2017) submitted

Constrained null models

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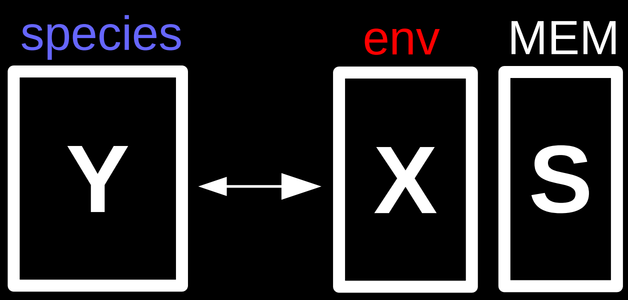

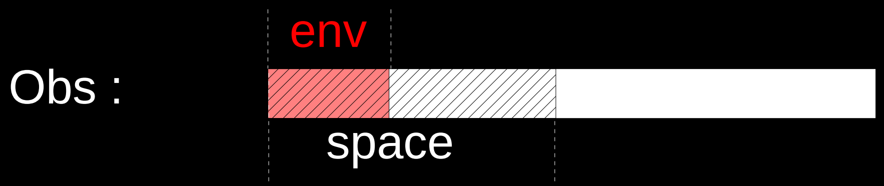

- Simulated data

Clappe et al (2017) submitted

Constrained null models

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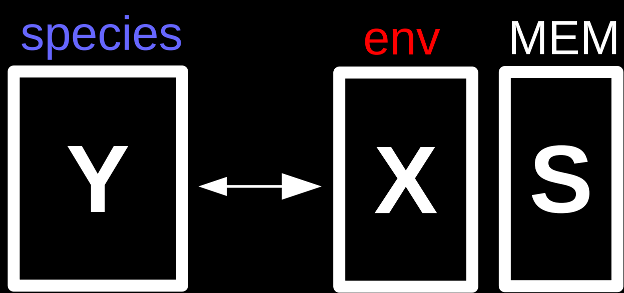

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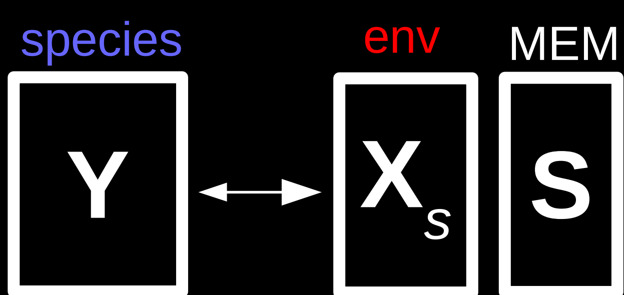

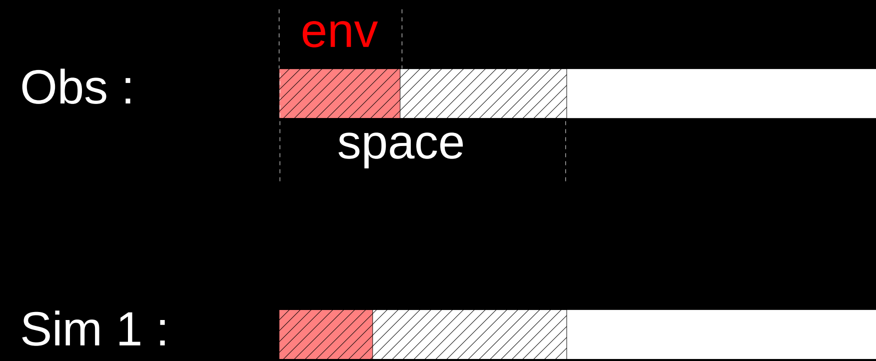

Clappe et al (2017) submitted

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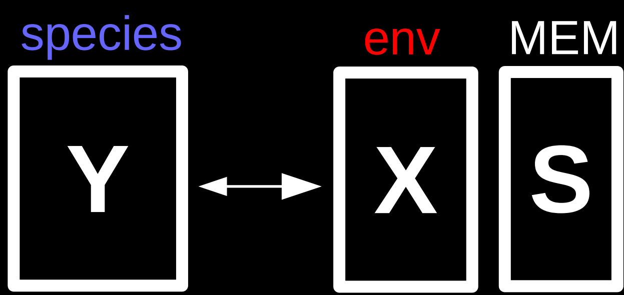

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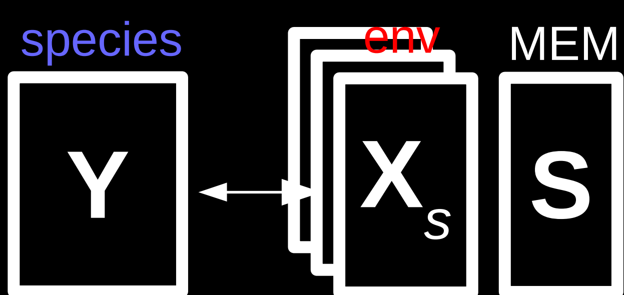

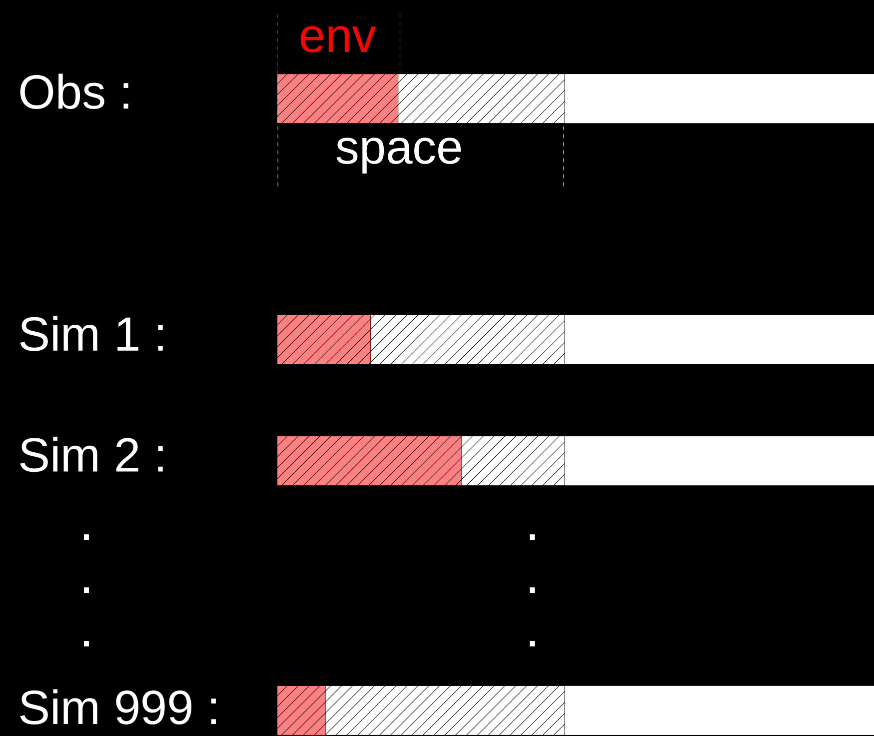

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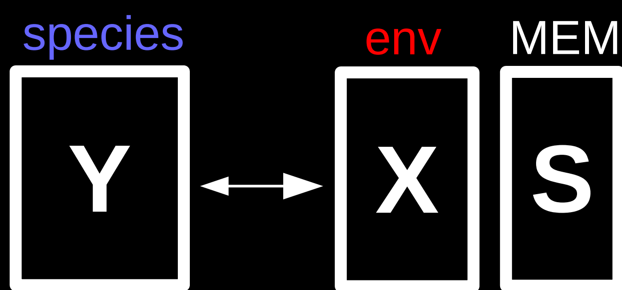

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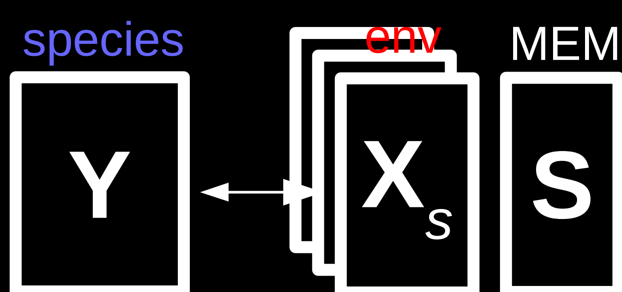
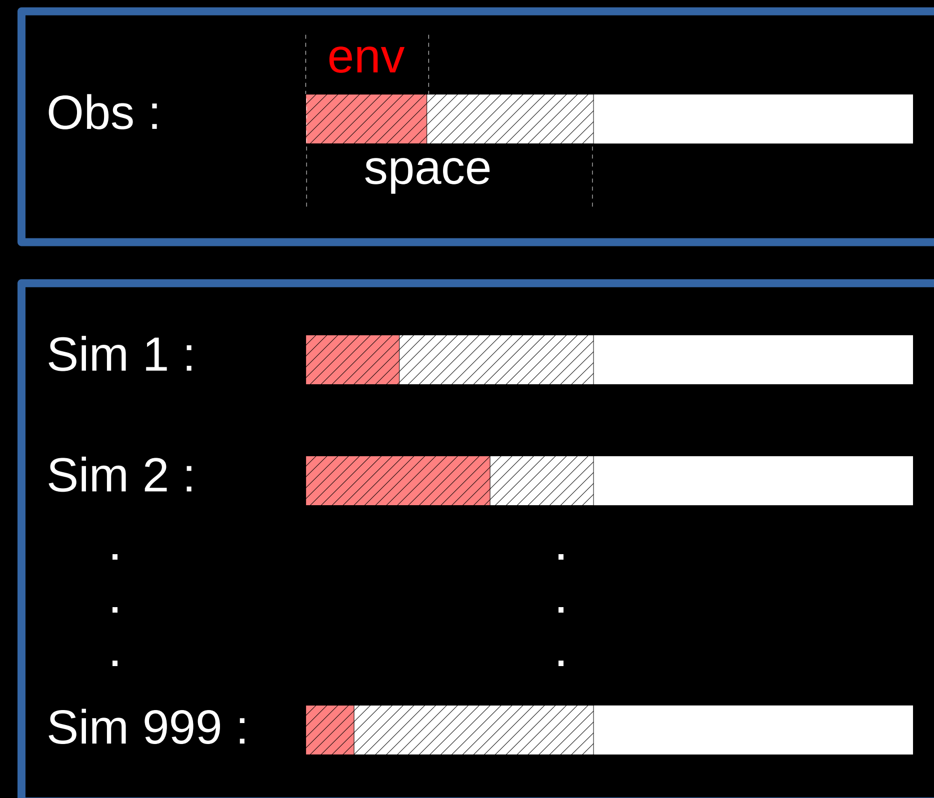


- Comparison



Clappe et al (2017) submitted

Constrained null models

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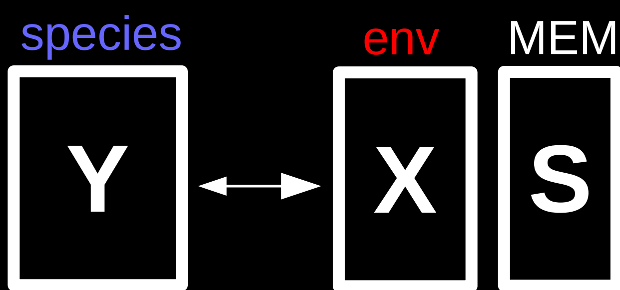

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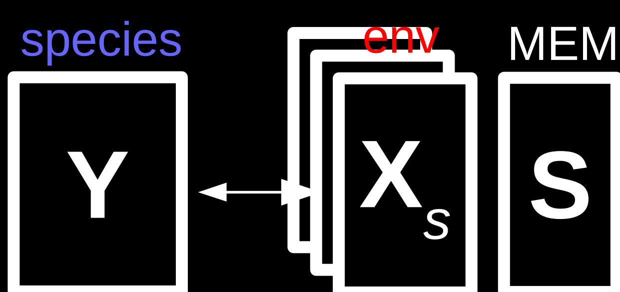

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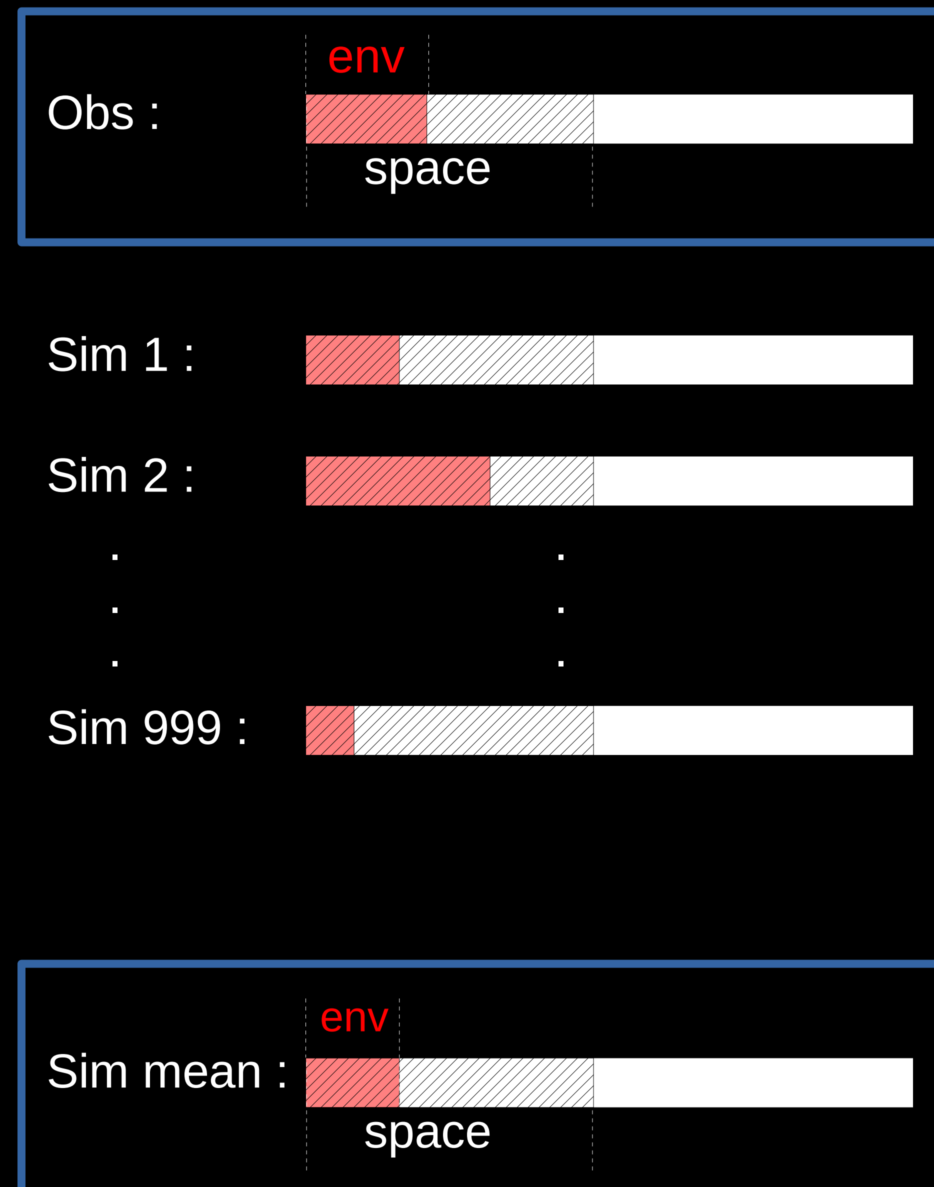


Clappe et al (2017) submitted

Moran spectral randomization

Moran's coefficient decomposition :

$$MC(\mathbf{x}) = \sum_{i=1}^{n-1} \lambda_i cor^2(\mathbf{x}, \mathbf{v}_i)$$

Variable decomposition:

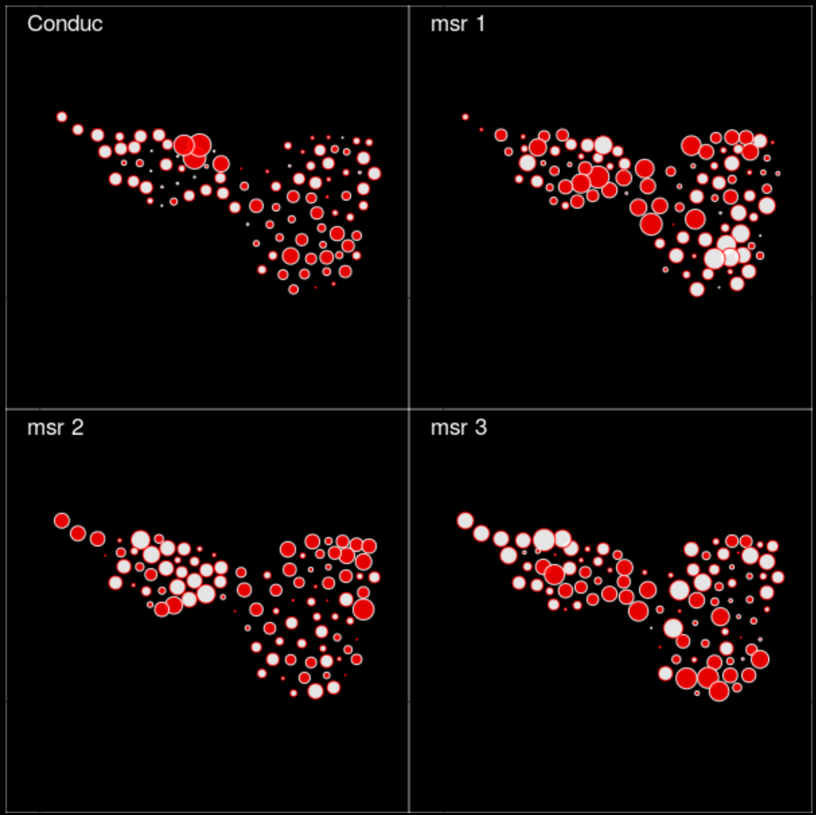
$$\mathbf{x} = \bar{x} + s(\mathbf{x}) \sum_{i=1}^{n-1} cor(\mathbf{x}, \mathbf{v}_i)\mathbf{v}_i$$

Random replicates:

$$\mathbf{x}_{sim} = \bar{x} + s(\mathbf{x}) \sum_{i=1}^{n-1} a_i \mathbf{v}_i$$

$$\text{with } a_i = \pm cor(\mathbf{x}, \mathbf{v}_i)$$

```
msr(X, mymem)
```



Wagner & Dray (2015) Methods in Ecology and Evolution

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Guillaume Blanchet

Naima Madi

Guillaume Guenard

GitHub

https://github.com/sdray/adespatial

Vignette

```
vignette("tutorial", package =
"adespatial")
```