Forestry and forest bird habitat: a quantitative compromise

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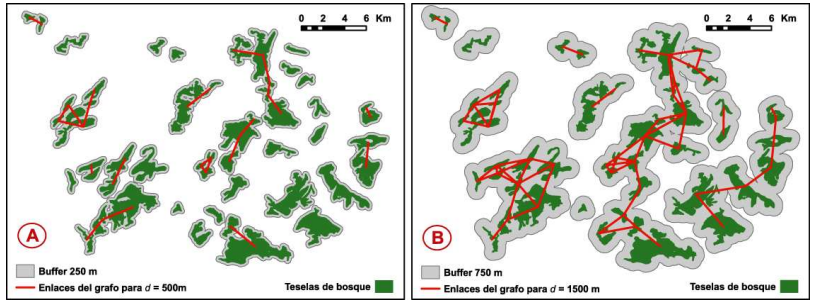
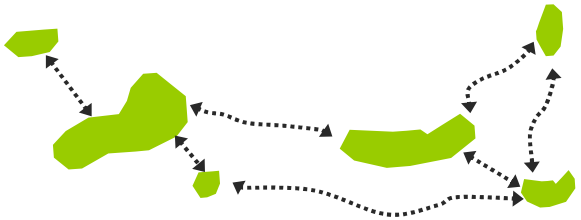
Forests as multifunctional spaces in a changing context

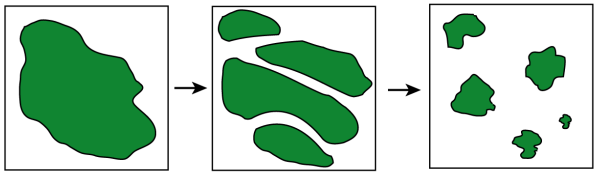
- New society demands, new management goals.
- From timber management to ecosystem management (biodiversity conservation, climate change mitigation, etc.)
- Growing research needs to support decision-making for the new objectives and context
  - Impacts of society in forest ecosystems. Spatial prioritization of conservation targets, reserve design, networks of protected areas, forestation measures, etc.

Network analysis and forest landscape connectivity

- **Landscape connectivity**: degree to which the landscape facilitates the movements of genes, species and other ecological flows
- Connectivity is crucial for the conservation of forest biodiversity and to allow adaptation of species to climate change.
- Connectivity is functional, species-specific: spatial arrangement of forest habitat patches (structural) + dispersal abilities of the species (functional).

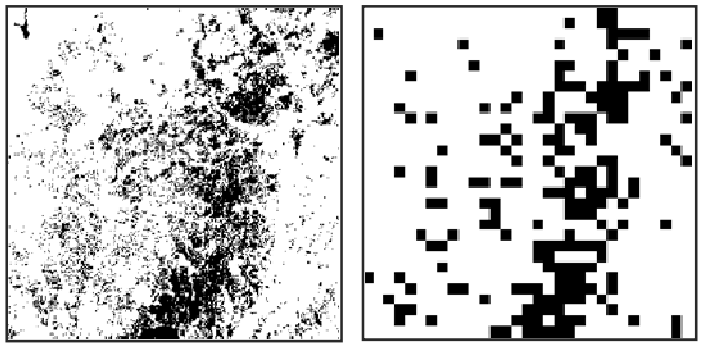


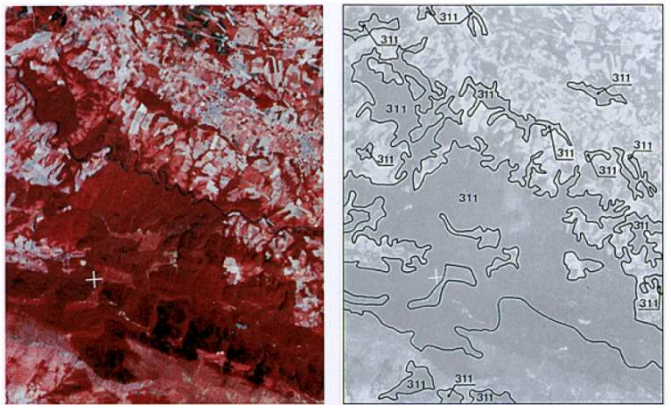


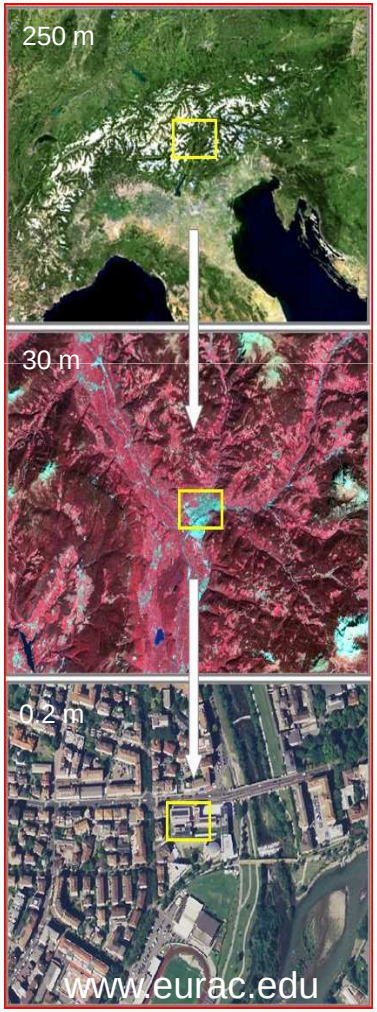


The observational scale: where do nodes and links start?

- Unlike in some other networks, nodes are not univocally identified.
- Depends on the scale of analysis and the spatial resolution of source data (typically remote sensing).
- Within-patch networks and connectivity below the observational threshold







Need to support decision making in forest planning

?

Which habitat patches and corridors are more critical for the maintenance of forest landscape connectivity?

$$dPC_k = 100 \cdot \frac{PC - PC_{remove,k}}{PC}$$

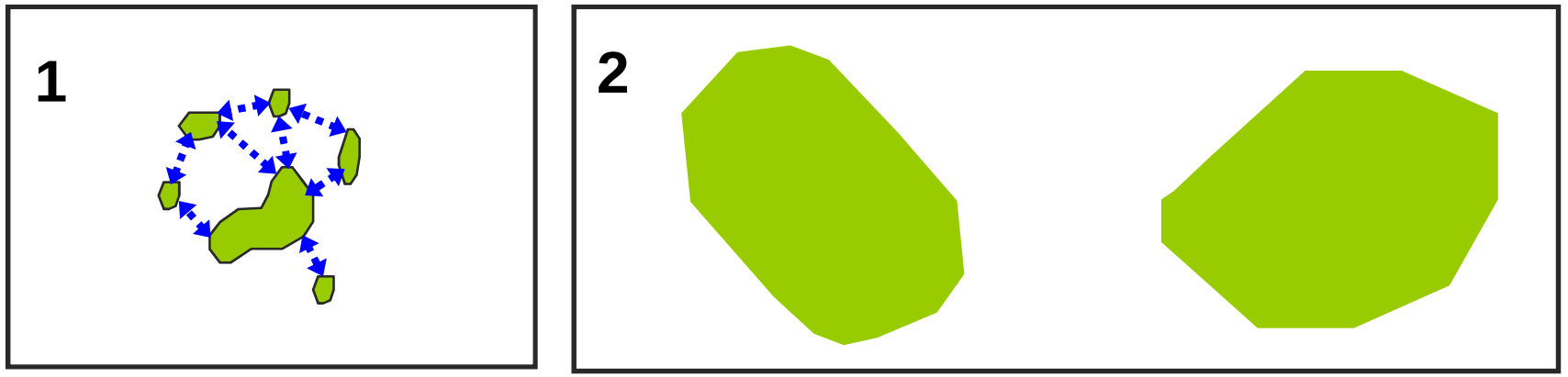
- It is not just a descriptive analysis

- It is a decision-support analysis oriented to forest planning

→ Priority sites for conservation, restoration, forestation, etc.

Paradoxes of only measuring connectivity between patches

- Which landscape is more connected? (1 or 2)
- Which nodes / habitat patches are more important?



- Need to measure habitat availability at the landscape scale.
- A node / patch is considered as a space where connectivity exists.
- Habitat availability metrics integrate the area within habitat patches (*intrapatch connectivity*) with the area made available by the connections between patches (*interpatch connectivity*).

NEW LANDSCAPE CONNECTIVITY METRICS

- UNWEIGHTED GRAPHS (Pascual-Hortal & Saura 2006)

Integral Index of Connectivity (IIC)

$$IIC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{a_i \cdot a_j}{1+nl_{ij}}}{A_L^2}$$

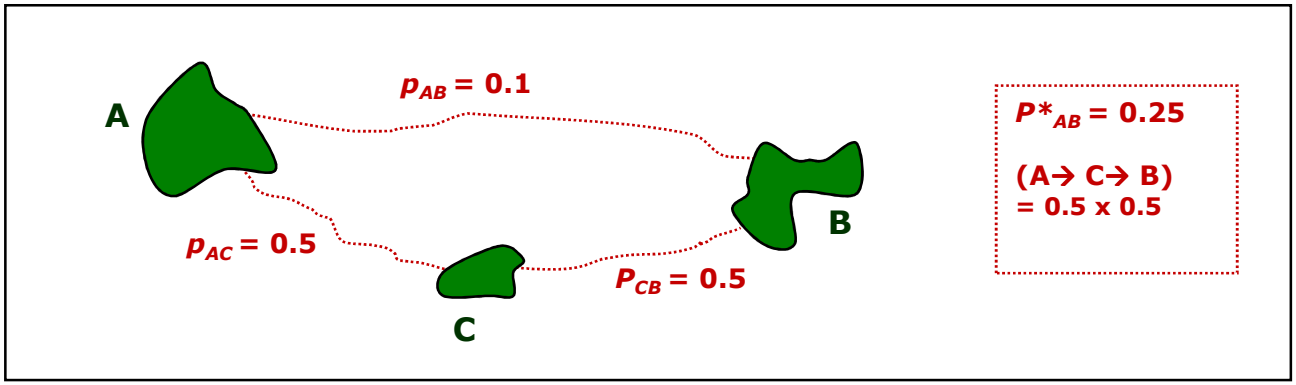
nl = topological distance (no. of links)

- WEIGHTED GRAPHS (Saura & Pascual-Hortal 2007)

Probability of Connectivity (PC)

$$PC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} a_i \cdot a_j \cdot p^*_{ij}}{A_L^{\,2}}$$

Probability that two points randomly placed within the landscape fall into habitat areas that can be reached from each other given a set of habitat patches and links.



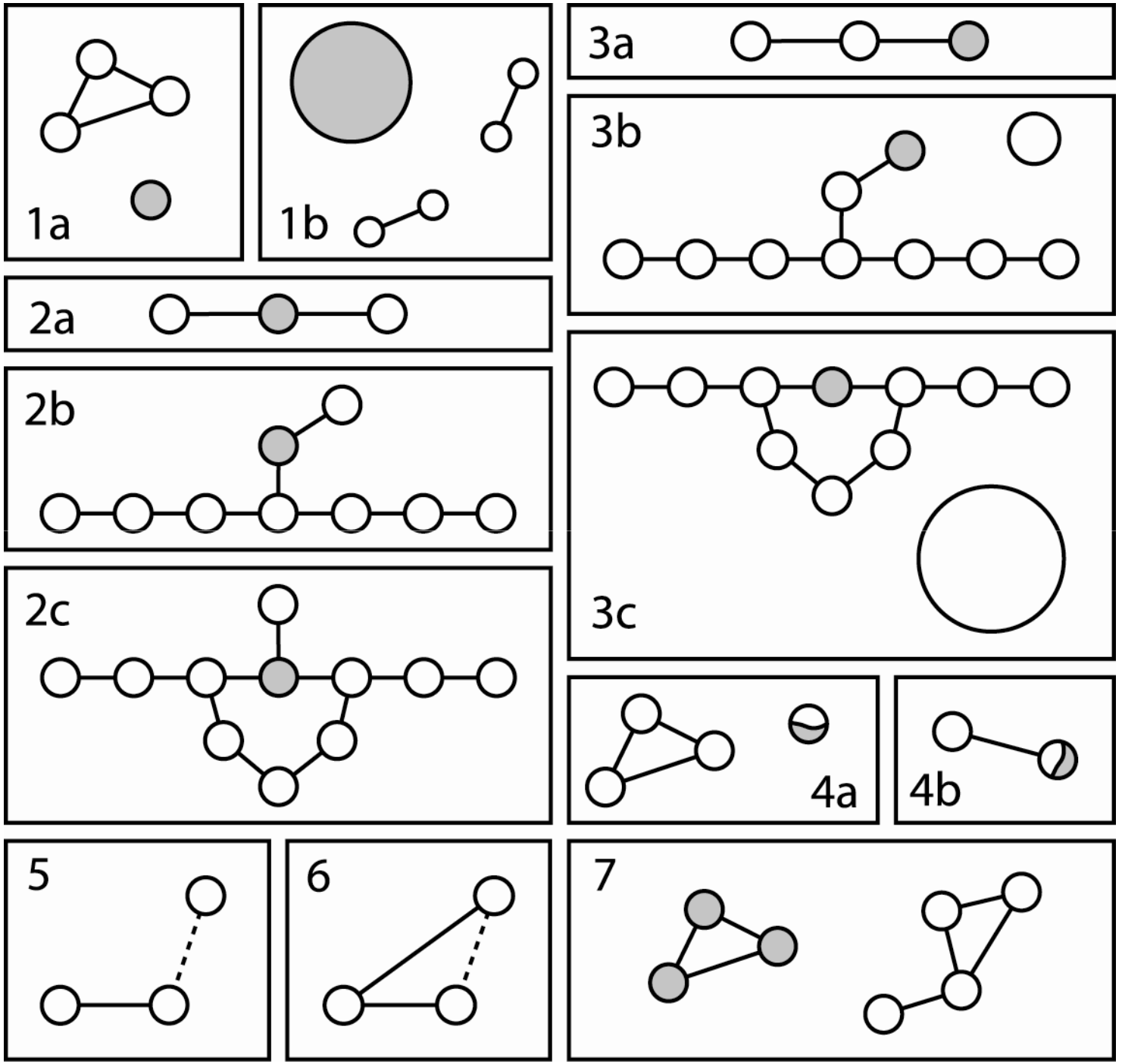
a_i, a_j: patch attribute (area, habitat quality, etc.)

p^*_{ij}: maximum product probability

p^*_{ij} =1 when i=j, $p^*_{ij} \geq p_{ij}$

A_L: maximum landscape attribute

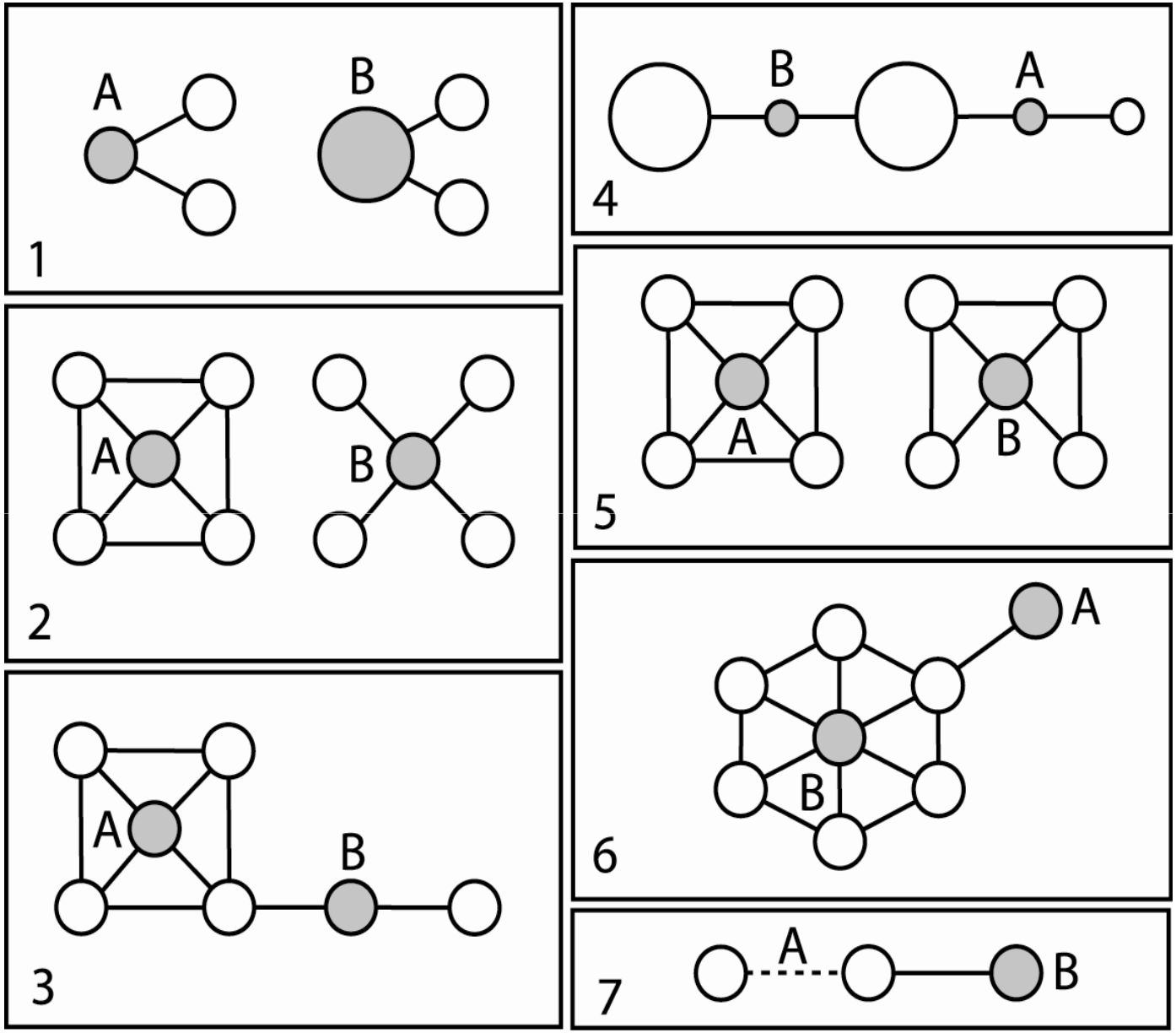
ADEQUATE INDEX REACTION TO THE LOSS OF LANDSCAPE ELEMENTS (patches, links…)



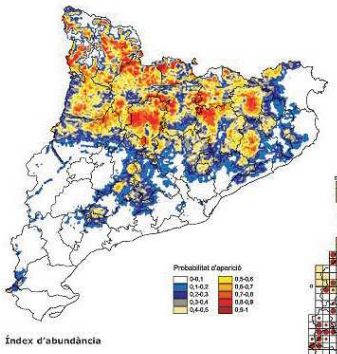
IDENTIFICATION OF THE MOST IMPORTANT (CRITICAL) LANDSCAPE ELEMENTS FOR CONNECTIVITY

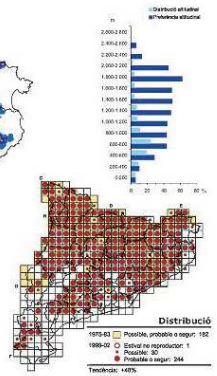
(INDEX PRIORITIZATION ABILITIES)

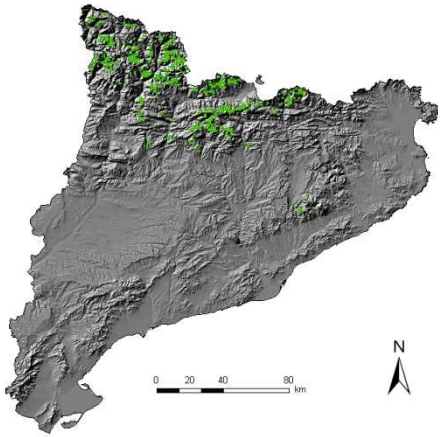
Loosing B is considered worse than A



Application to forest planning: capercaillie in Catalonia (NE Spain)



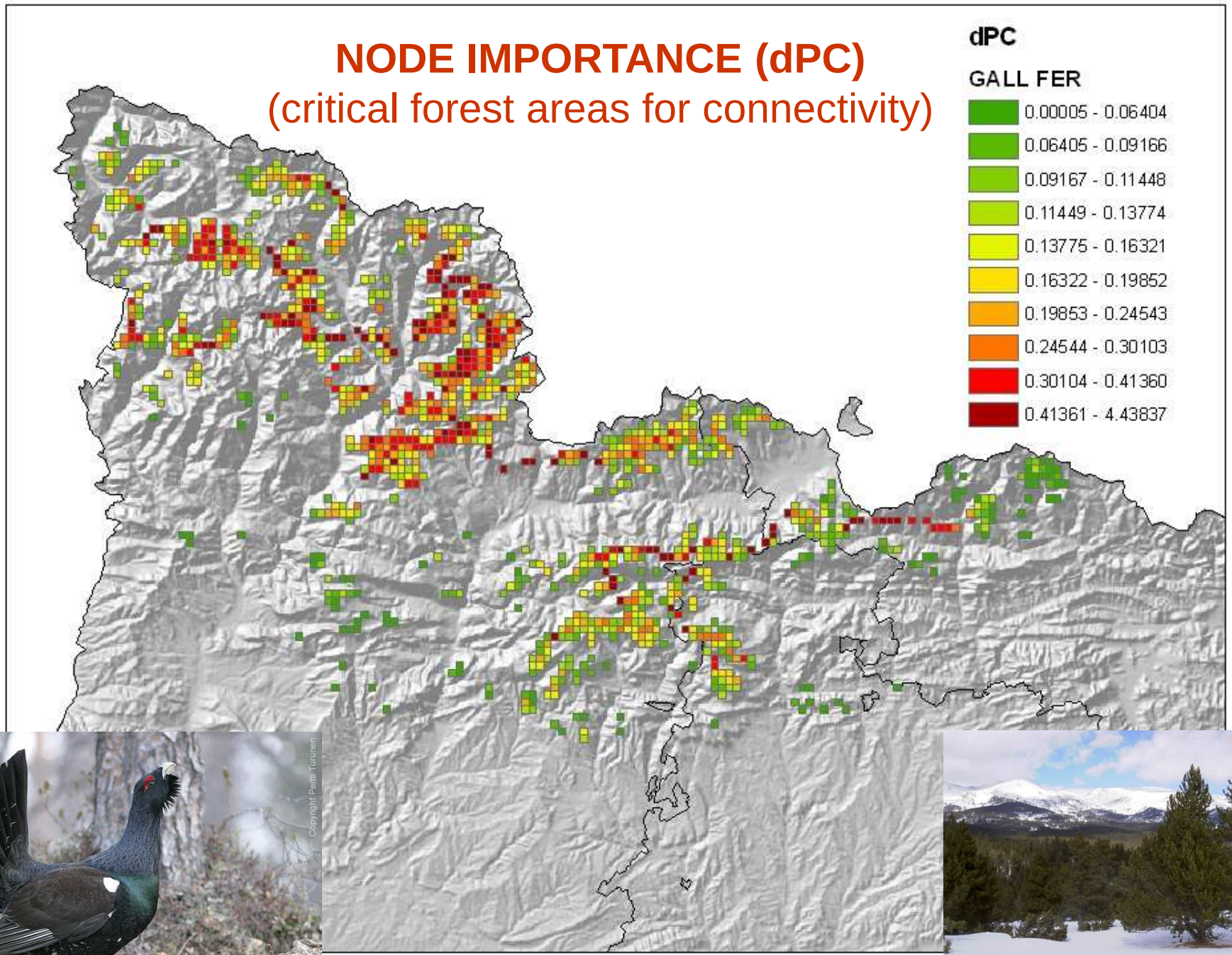




- Endangered species, fragmentation-sensitive. ≈ 586 males
- Upper montane and subalpine forests (Pyrenees)
- Habitat data: Field surveys from the Catalan Breeding Bird Atlas + niche-based modelling (maximum entropy method)
- Nodes: 1 x 1 UTM cells. Attribute: probability of occurrence (≈ habitat quality) (threshold 0.2)
- Link weight: mean dispersal distance 2,3 km (radiotracking)

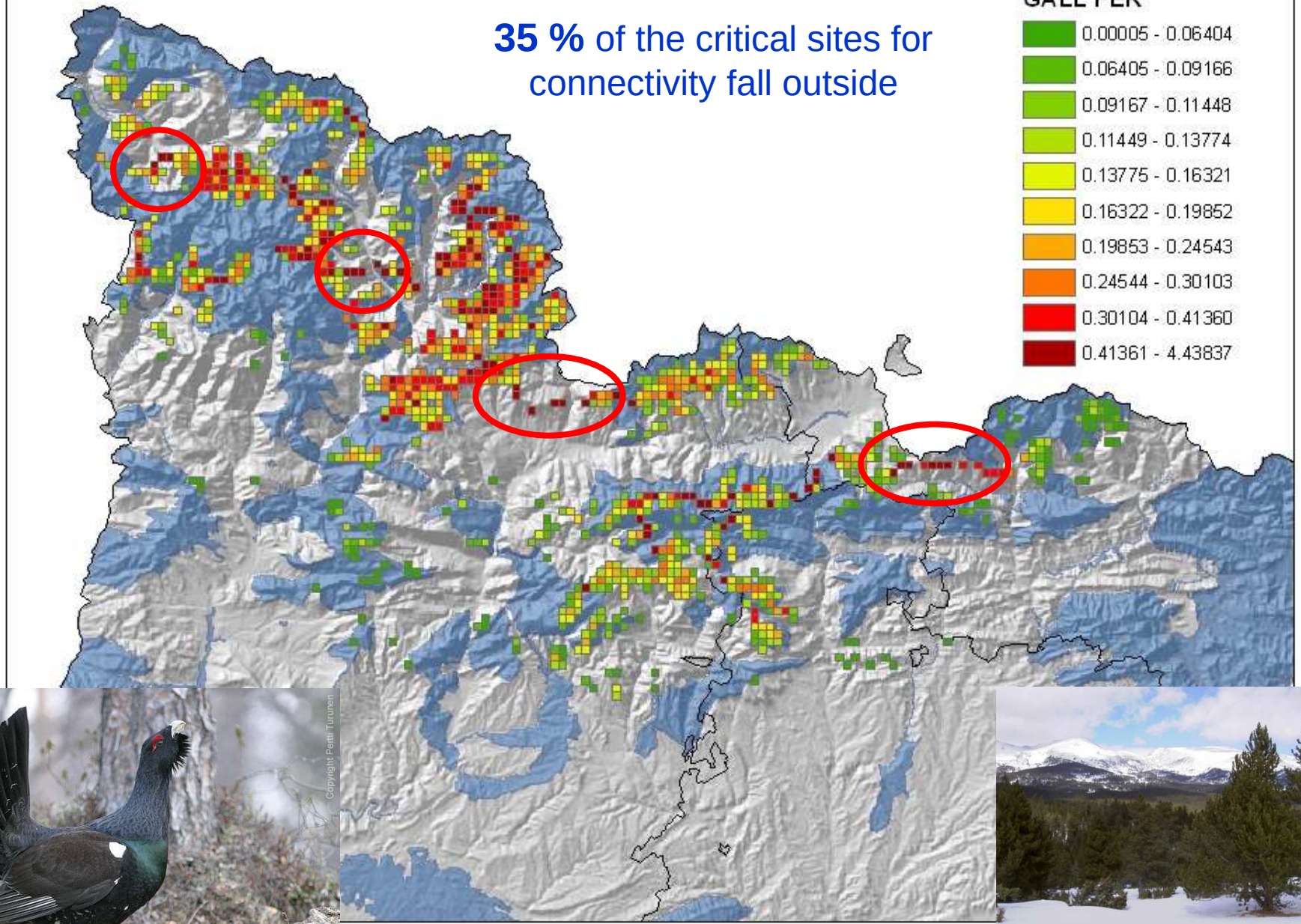
NODE IMPORTANCE (dPC)

(critical forest areas for connectivity)

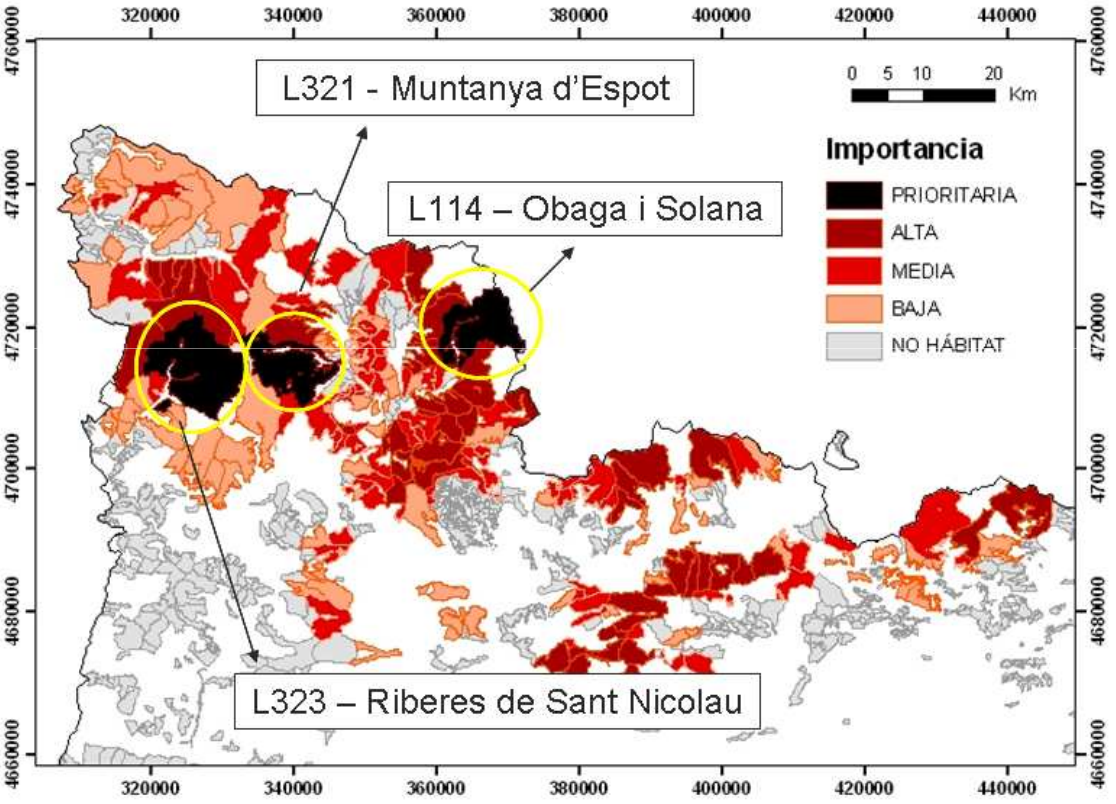


NATURA 2000 NETWORK

35 % of the critical sites for connectivity fall outside



Public forests, critical areas, and management guidelines



Forest management:

- High spatial heterogeneity
- Canopy cover ≈ 50%
- Uneven-aged stands
- Ecotone creation (clearcuttings ≈ 0.5 ha)
- Favour shrub species (*V. myrtillus*, bilberry)
- Forest treatments september-november
- etc.

Partitioning habitat availability metrics (PC) in three different fractions

- Partitioning importance of patch k:

$$dPC_k = 100 \cdot \frac{PC - PC_{remove,k}}{PC}$$

- Three different roles and ways in which patches (and links) can contribute to the connectivity and availability of habitat in the landscape.

$$dPC_k = dPC\text{intra}_k + dPCflux_k + dPCconnector_k$$

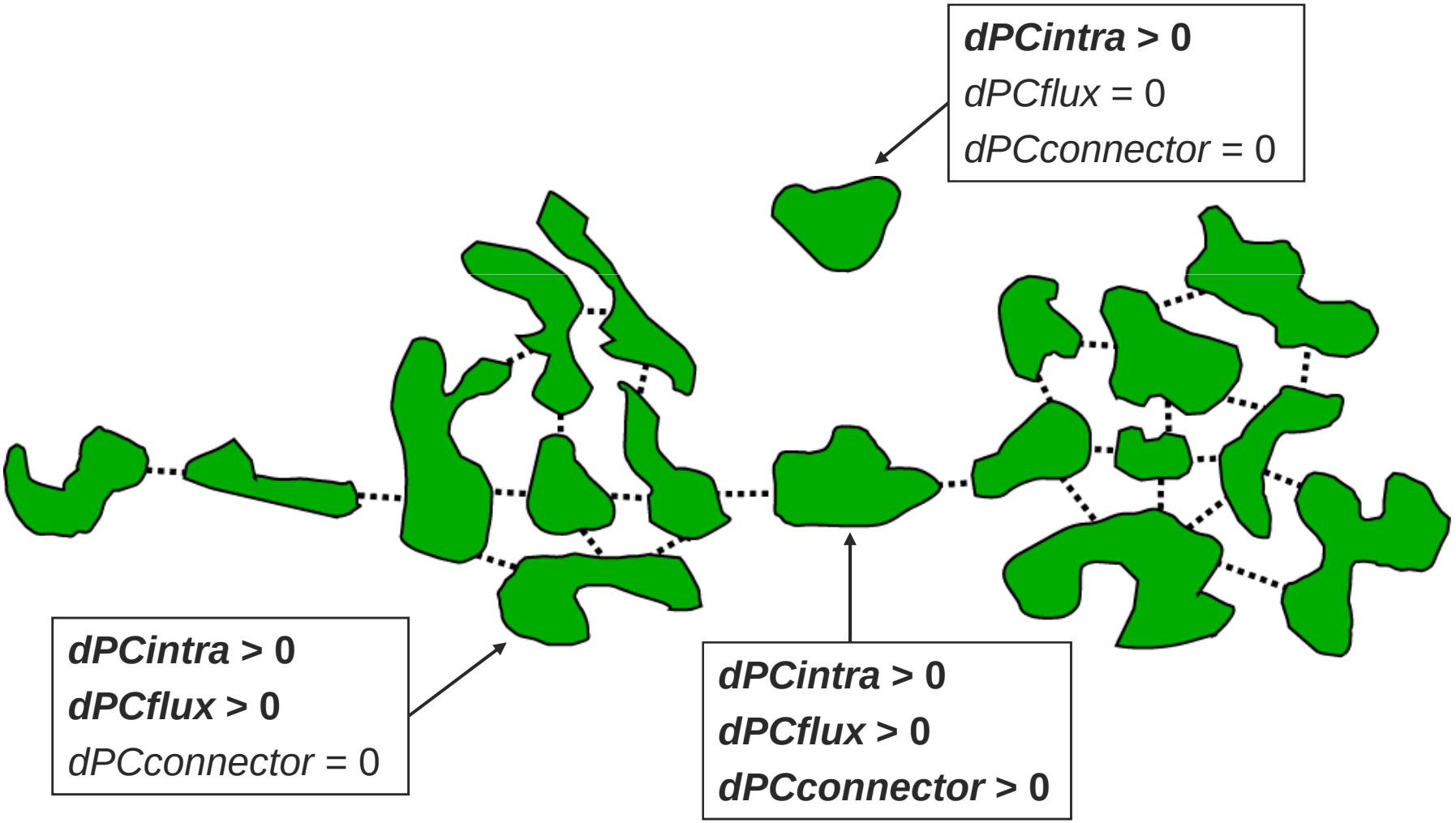
Partitioning habitat availability metrics (PC) in three different fractions

$$dPC_k = dPC\text{intra}_k + dPCflux_k + dPCconnector_k$$

Fraction	Definition / contribution	Network topology?	Intrinsic patch attribute?
dPCintra	Available habitat area provided by patch *k* itself through the area it comprises (**intrapatch connectivity**)	No	Yes
dPCflux	**Flux** of the connections of patch *k* with all the other patches when *k* is either the starting or ending node.	Yes	Yes
dPCconnector	Contribution of *k* to the connectivity between other patches, as **connecting element / stepping stone.** Only if *k* is in optimal path between them. Depends on alternative paths after losing *k*.	Yes (patches + links)	No

The different ways in which a patch / link can contribute to habitat availability and connectivity in the landscape

$$dPC_k = dPC\text{intra}_k + dPCflux_k + dPCconnector_k$$



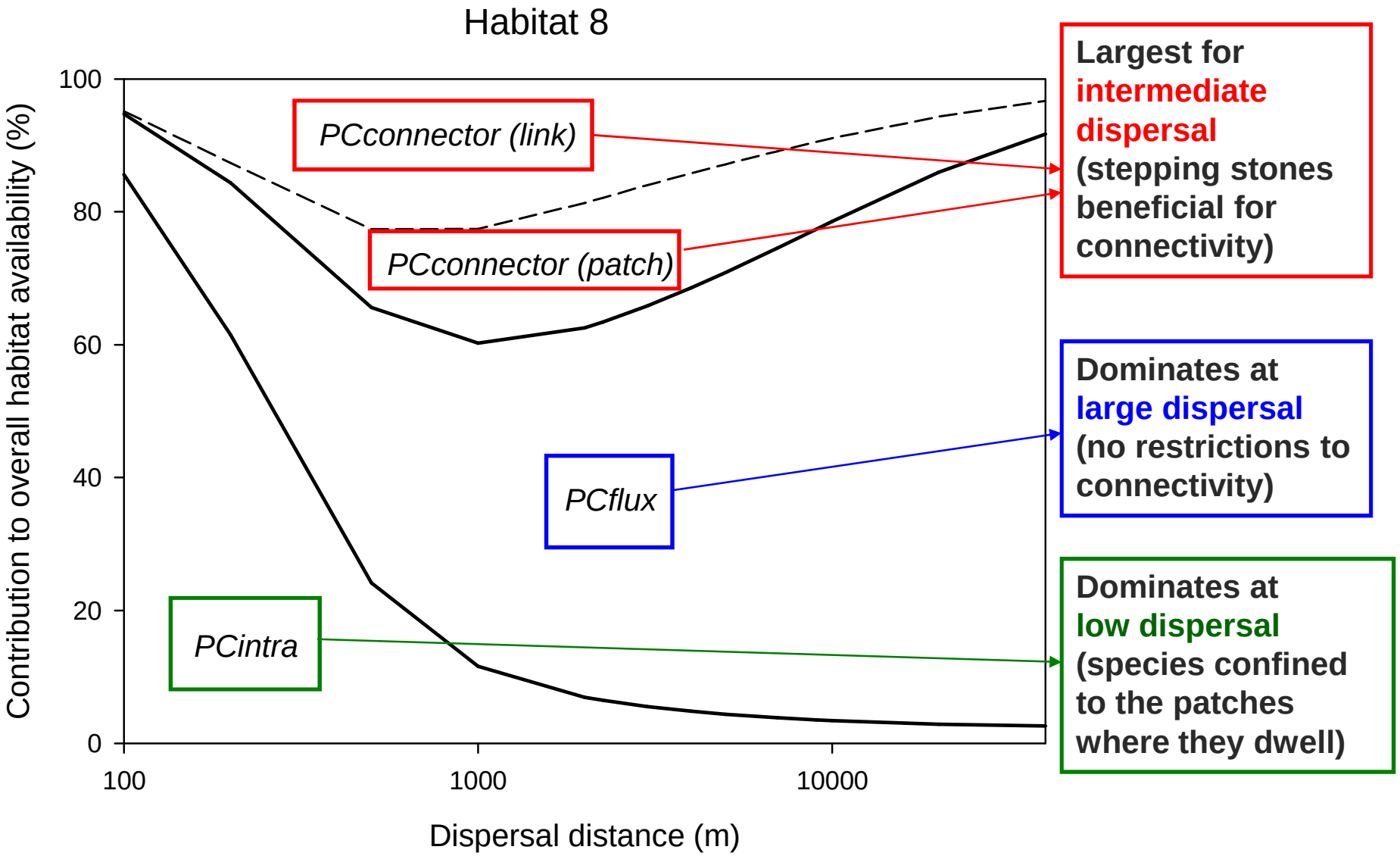
Intrinsic forest habitat characteristics vs. network topology: a planning trade-off?

- Basing decisions on intrinsic patch values (habitat quality, timber value) (A) vs. considering topology / connectivity (B).
- Is really network connectivity a key issue for forest planning and conservation? When?
- Trade-offs?
- Arbitrary weighting of planning / conservation alternatives?

- These questions are naturally and objectively solved by habitat availability metrics (e.g. PC).

- If connectivity is not a key issue, then dPC will provide the same result than A. Otherwise, it will provide the adequate weight to A & B in a single integrated approach resulting from the habitat availability concept.

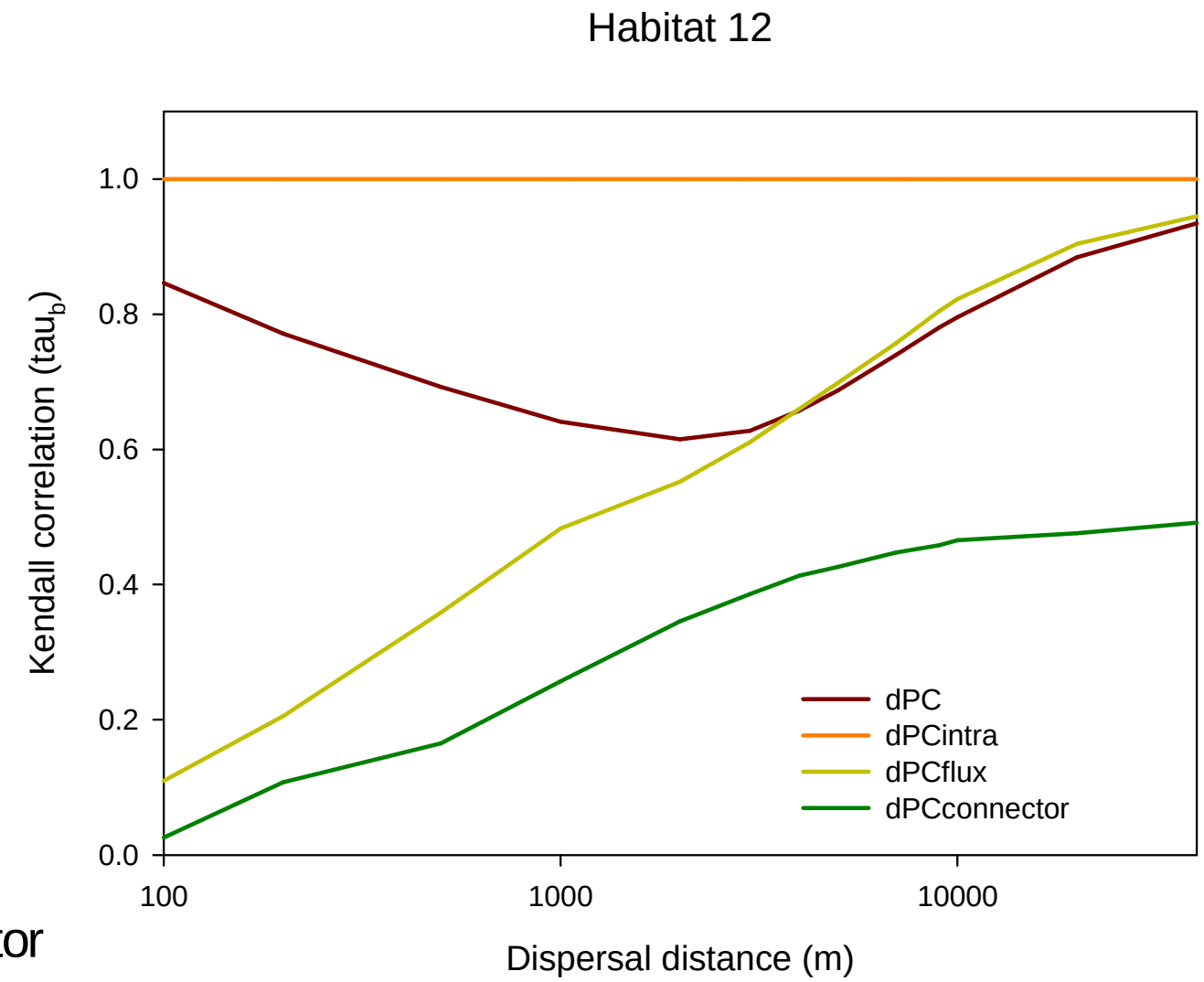
How do the different fractions contribute to overall habitat availability and connectivity?



Are the critical patches the same for the different fractions? Does prioritization differ from just selecting the best individual sites?

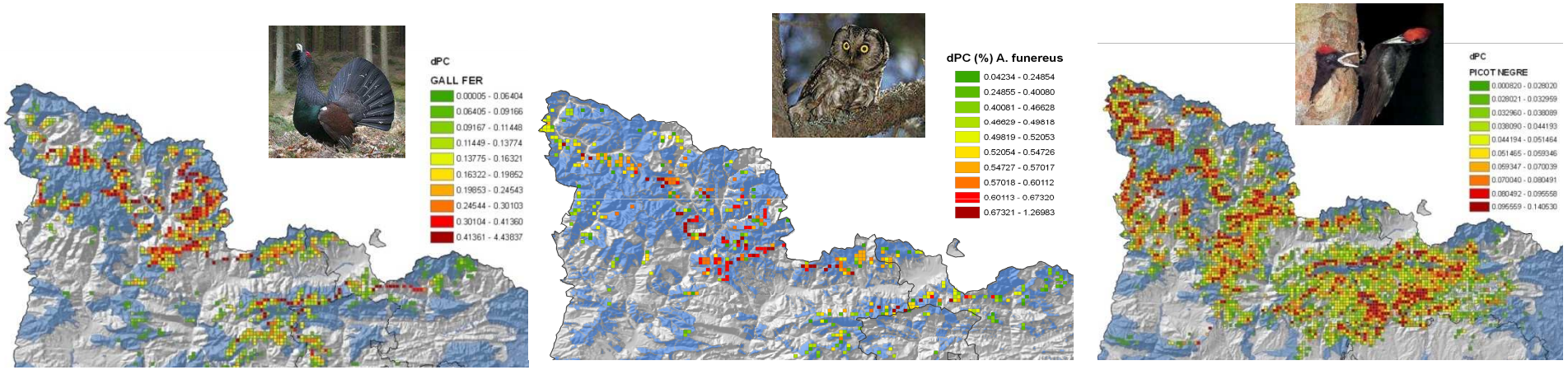
Rank correlation of dPC fractions with patch area (attribute)

- dPC
- dPCintra
- dPCflux
- dPCconnector



Multiple species-specific networks

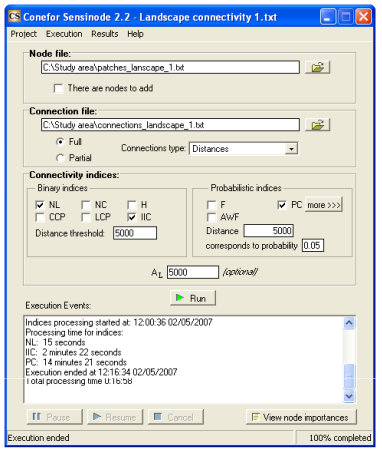
- Different landscape perceptions and networks within the same planning area.
- How to combine results for different networks?

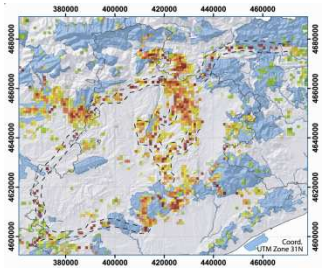


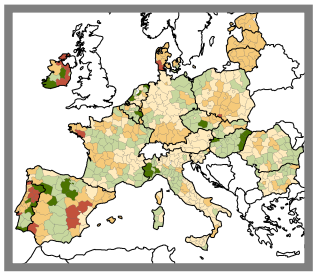
	Capercaillie	Boreal owl	Woodpecker
Habitat pattern	Fragmented	Fragmented	≈ Continous
Dispersal distance (km)	2.3	34.0	6.5
Max dPC	4.44	1.27	0.14
Proportion of dPC explained by intrinsic habitat attributes	20 %	75 %	98 %

Conefor Sensinode 2.2: graphs + habitat availability metrics

- Freeware & open source: **www.conefor.org**
- Oriented to the identification of critical areas for landscape connectivity
- User & planning oriented. GIS extensions
- Applications and case studies (2007-09):
  - o Forest and land planning in Spain
  - o Genetic diversity & connectivity in USA
  - o Forest connectivity trends in EU (EFDAC)
  - o Bird species colonization after wildfires in Spain
  - o River network connectivity for the otter in Italy
  - o More: Puerto Rico, México, Australia, etc.







Conclusions

- Network science is useful and necessary to respond to new demands related to forest management and biodiversity conservation.
- There are specific needs and particularities that require from specific solutions and approaches for forest and landscape planning.
- Network analysis should be placed within a broader context of forest planning and conservation alternatives.
- New network metrics (habitat availability) and tools (e.g. Conefor Sensinode) are recently available and are beginning to be used for these purposes.

Thank you! santiago.saura@upm.es