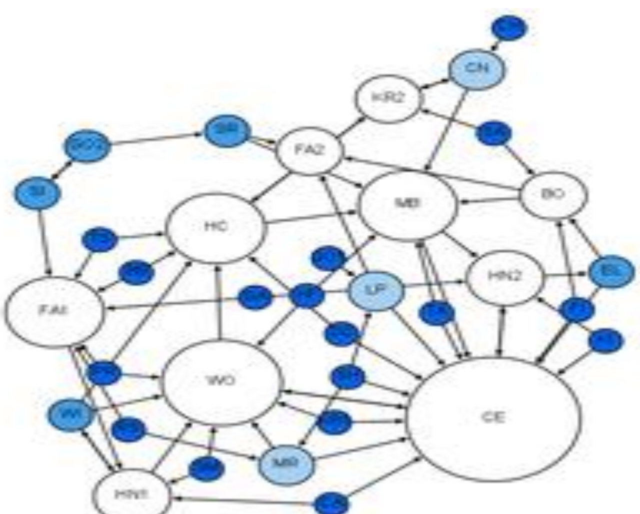
Università degli Studi di Padova

# Network science

2022 – 2023

Nguyen Xuan Tung & Farin Binta Zahir

## Structure of interactions and different models of ecological network



Physics of Data

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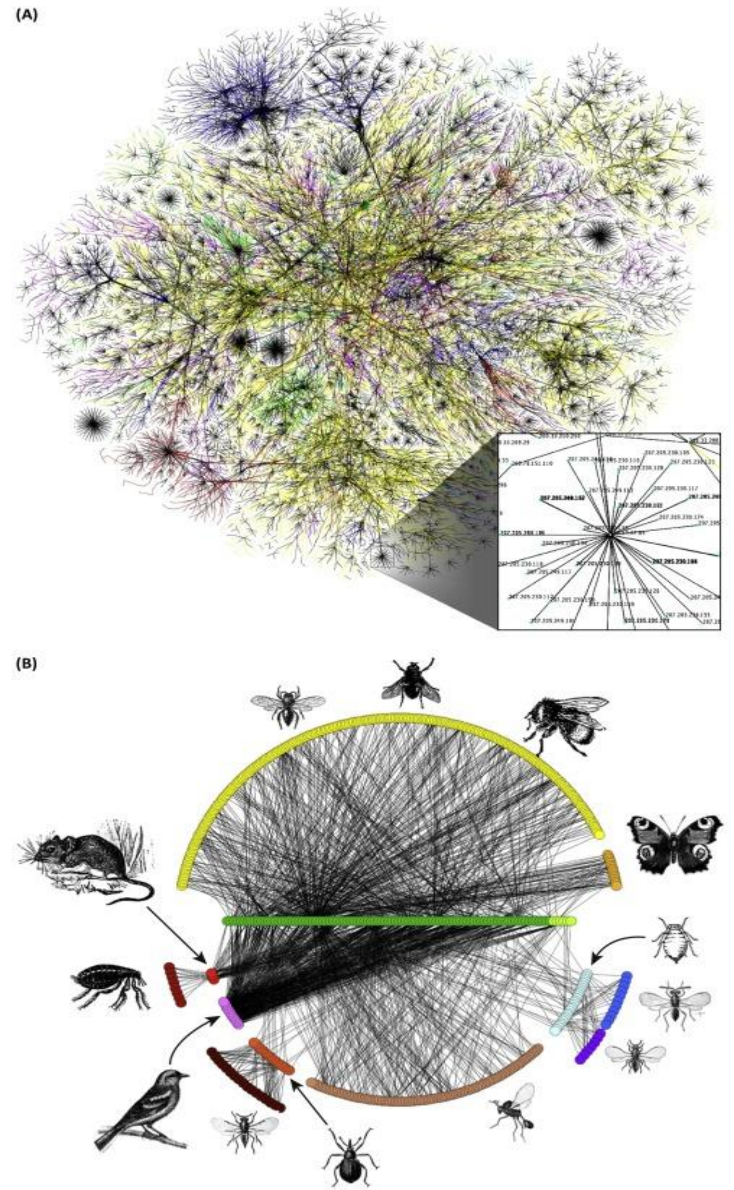
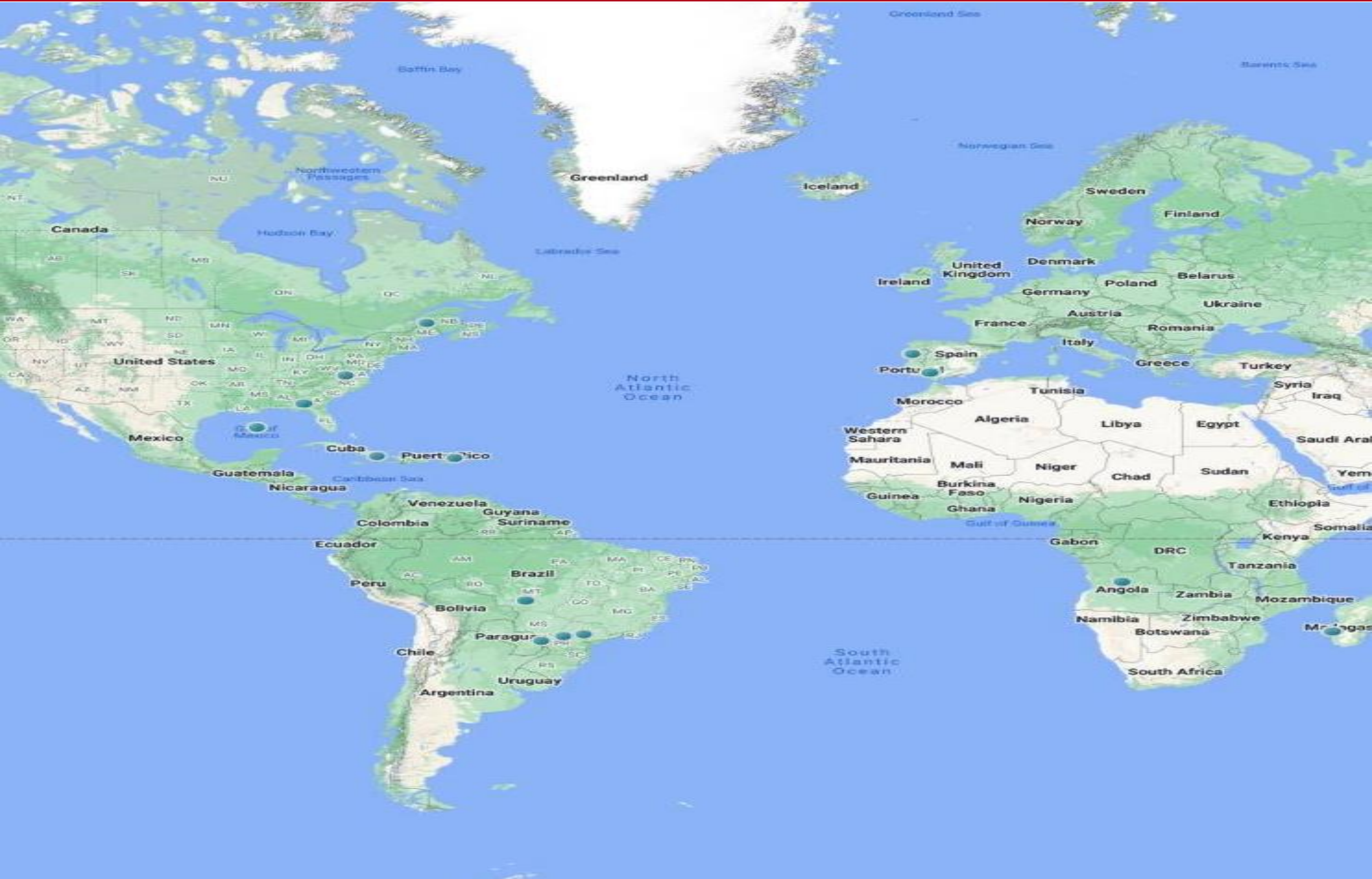
# Introduction

Goal of the project:
- Create the empirical food web based on real dataset.
- Study the structures of the network.
- Community detection of the network.
- Create the matrix network and compare with the empirical network



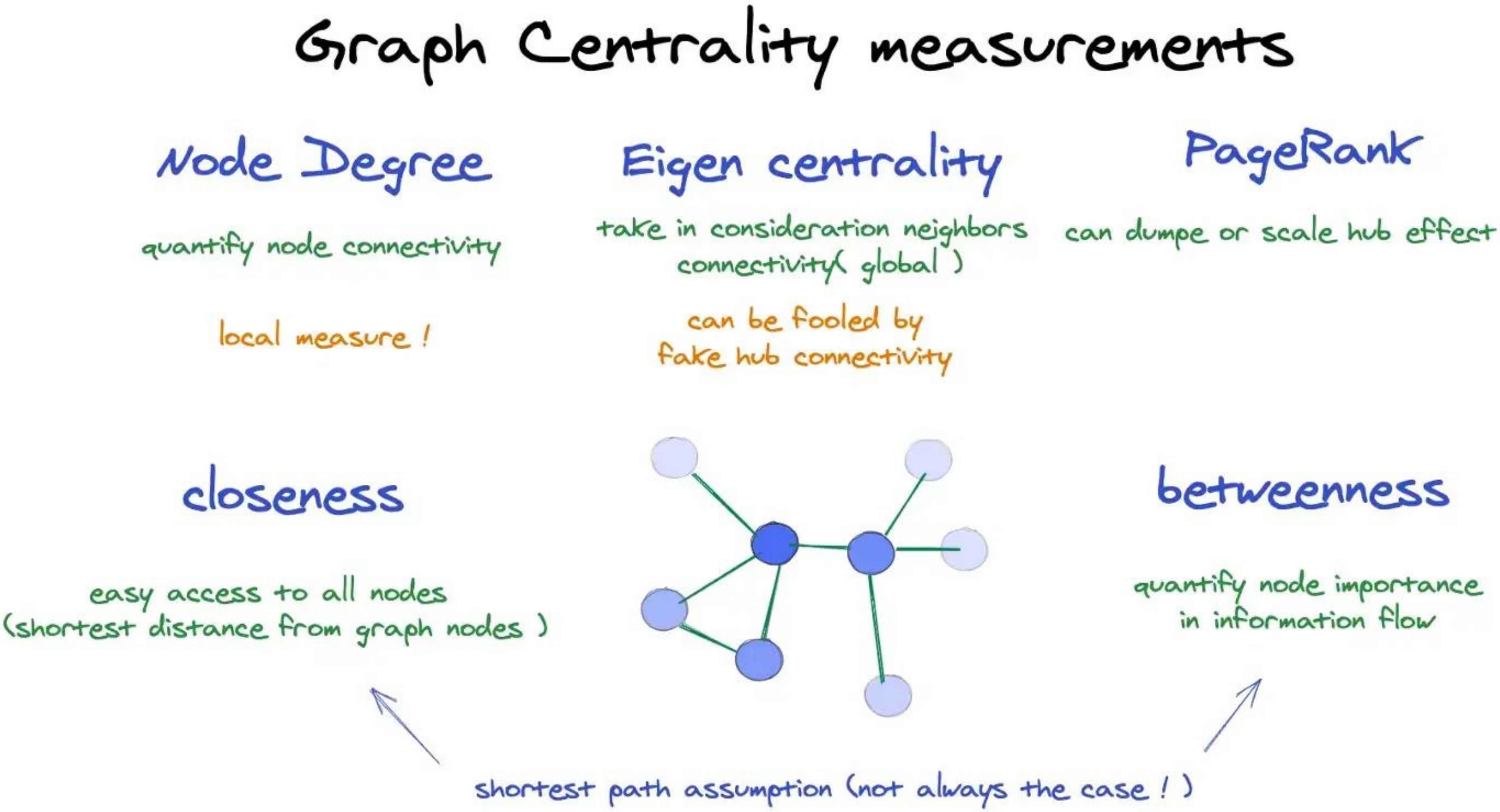

Trends in Ecology & Evolution

# Data collection



# Empirical network: Centralities

- The degree centrality counts an entity’s number of links with different perspective.

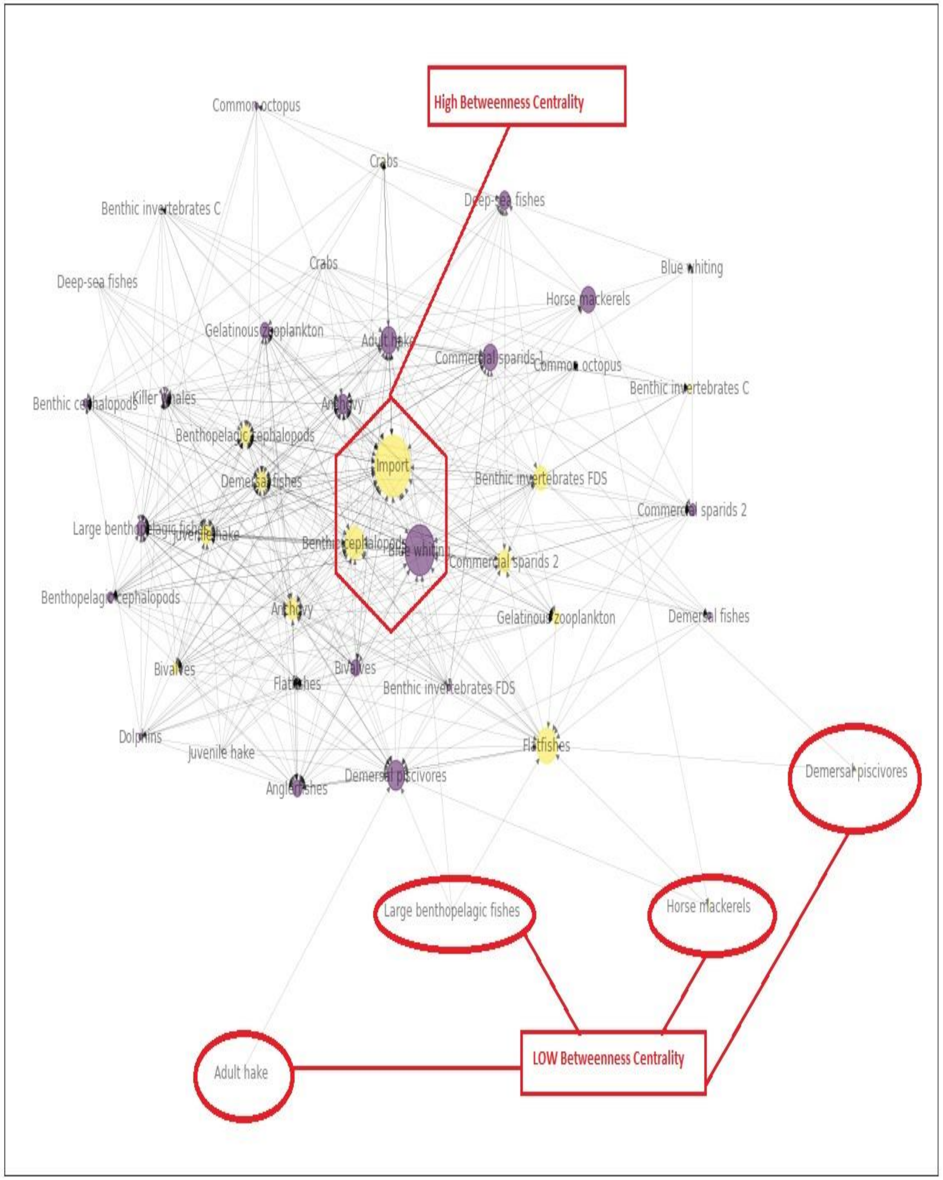


# Empirical network: Betweenness Centralities

- Betweenness centrality is a way of detecting the amount of influence a node has over the flow of information/dependencies in a graph.

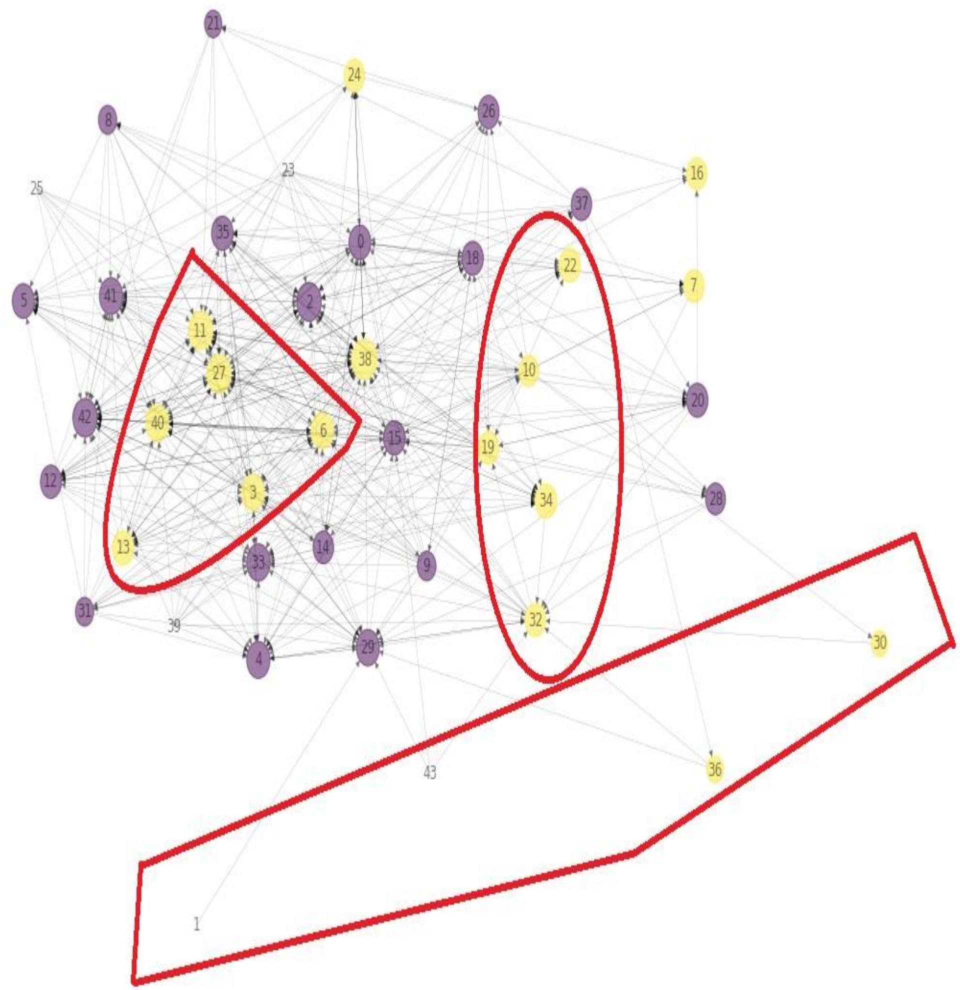
- It is a measure of how often a node is a bridge between other nodes.

- Node with high Betweenness centrality are often important controllers of power or information.



# Empirical network: **Closest** Centralities

- The node with the highest closeness centrality is the closest one to all other nodes.
- It takes fewest steps for anyone to reach .
- The closeness centrality is based on how long the paths connecting an entity with the others are.

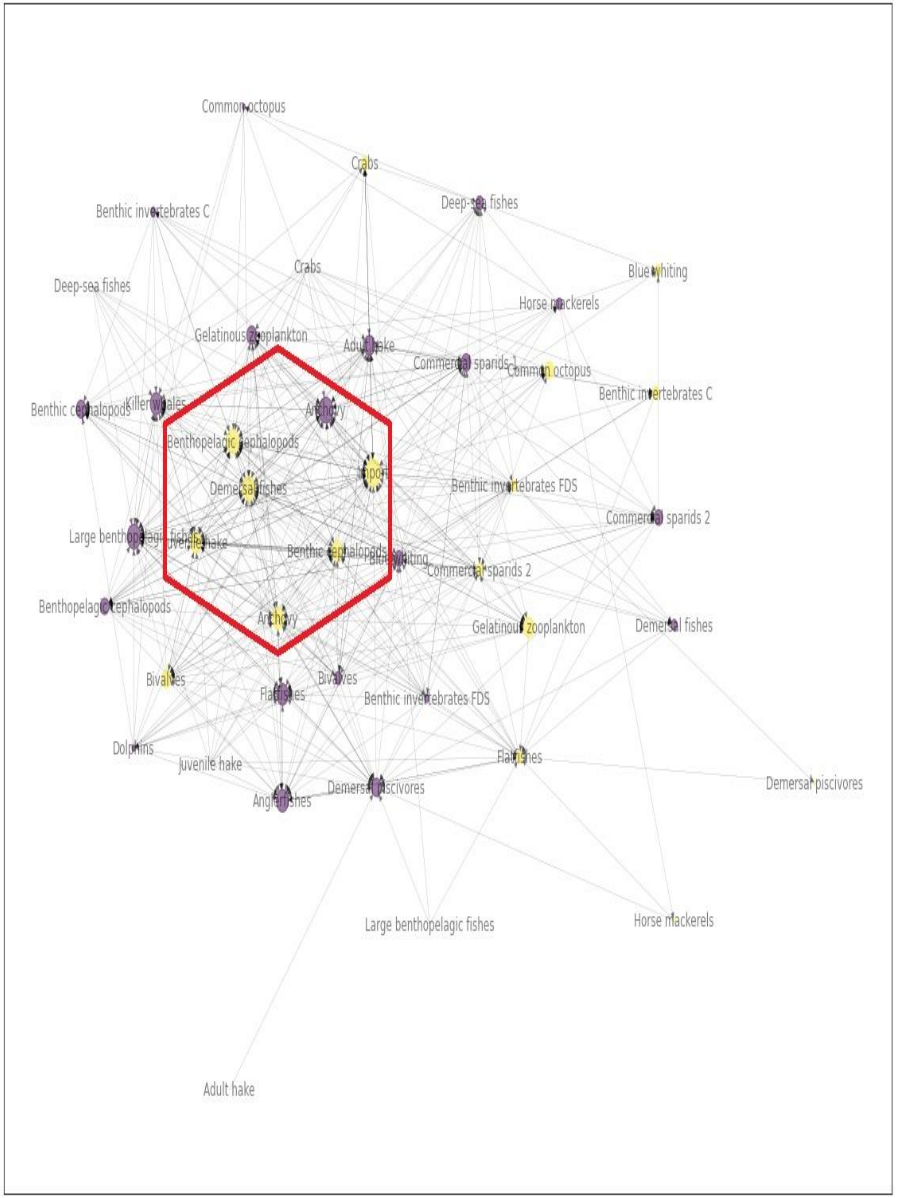


# Empirical network: Eigenvector Centralities

- This measure indicates how important an entity is, based on how important the entities in contact with it are. In other words, the eigenvector centrality reveals which entities are better connected to important entities in the network.

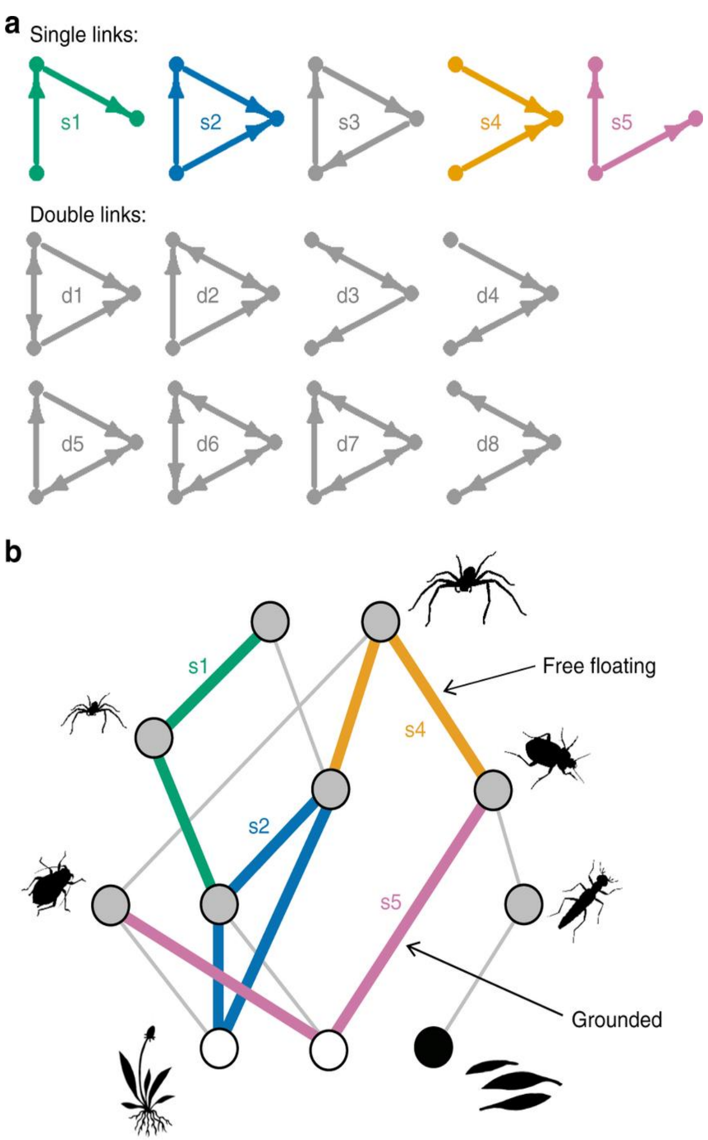
- It is not about "linking power" or how easy they make to reach .

- It is not about the quantity, but the quality of the connections: "few but good".



# Empirical network: Motif analysis

- Food webs have been found to exhibit remarkable “motif profiles”, patterns in the relative prevalences of all possible three-species subgraphs, and this has been related to ecosystem properties such as stability and robustness.
- This study mainly focuses on the 3-node substructures and the representation of their significance profile.
- This study reveals the quantitative analysis of their local structure.

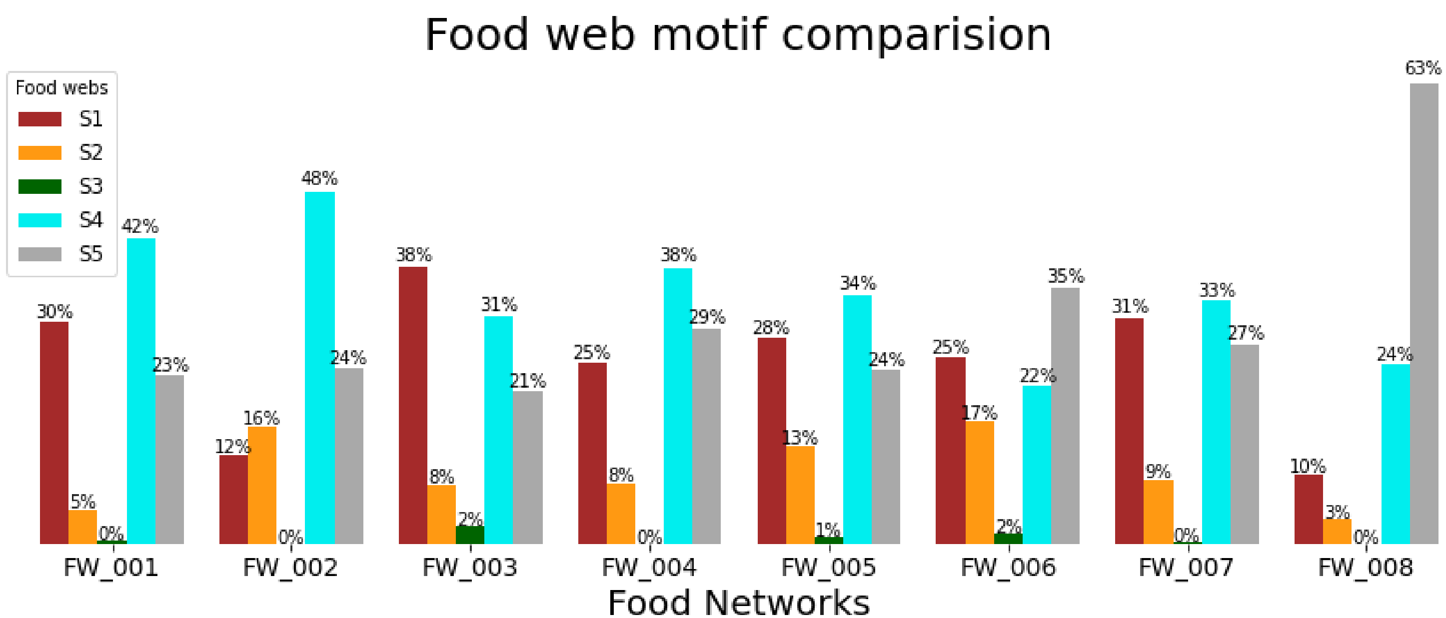


# Empirical network: Motif analysis

- The figure shows us that from all of 8 networks the numbers of 3-node cycle motif type do not exist or exist in a small number.

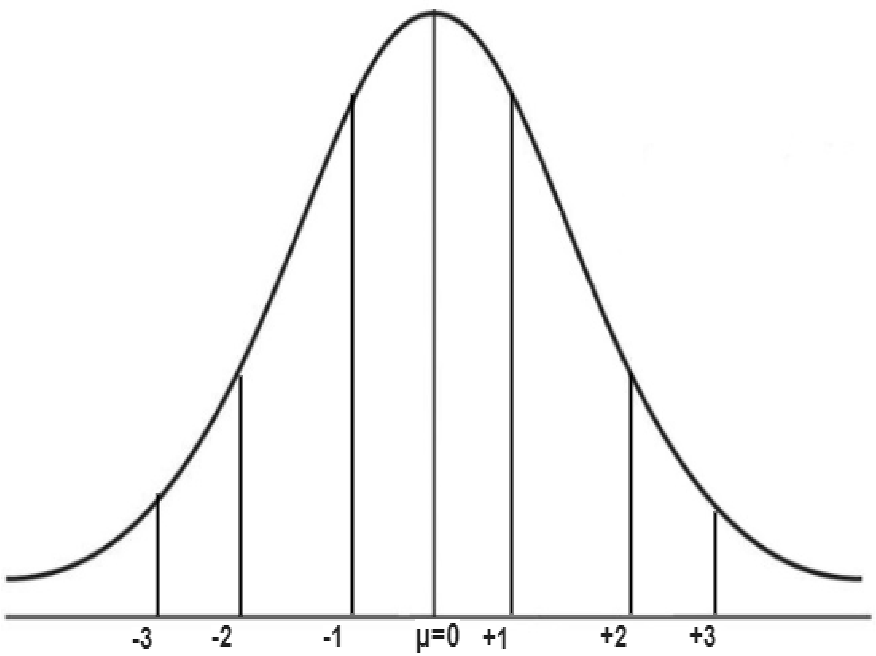
- The network will generally have cycles with path length more than 3.

- We can conclude that species in our network mostly come from basal and top species, which can be seen in the graph that 4th and 5th type of motif are dominant.

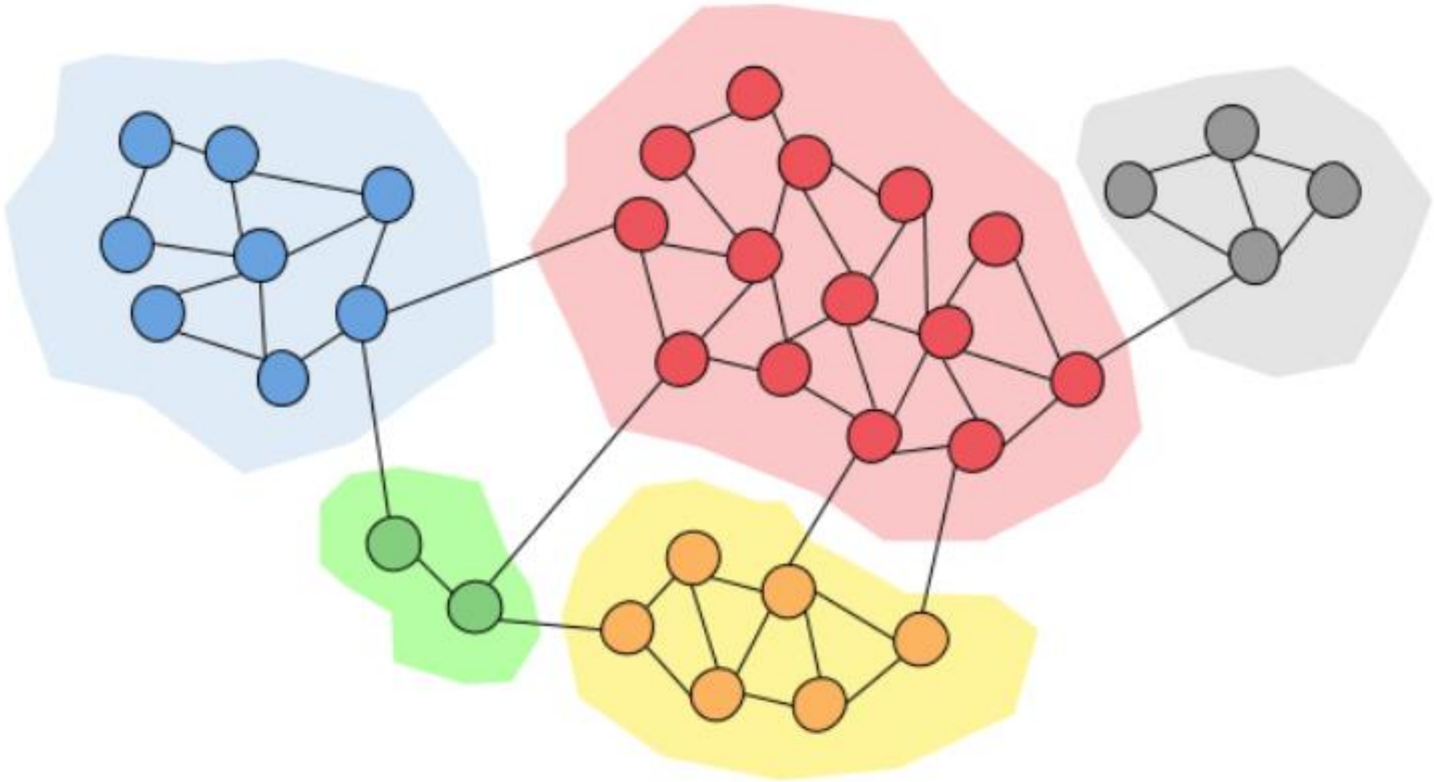


# Empirical network: Motif analysis

- We also analyzed the G-score for each network which provides statistical significance.
- After analysis of Z-Score, we have come to the point that we have two negative values on average in every set of the network and the remaining all are positive.
- The positive values of the Z-scores interpret that they are above the mean, and negative Z-scores are from values below the mean.



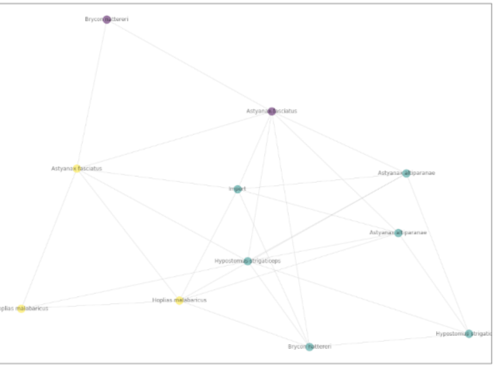
# Community detection analysis



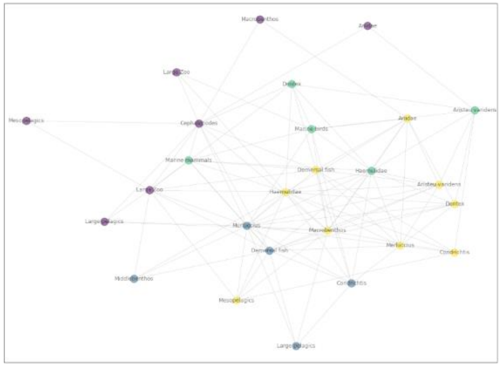
Louvain algorithm which optimizes the modularity to form communities is used on this network to form communities.

The method is a greedy optimization method that appears to run in time O(n*log(n)) where n is the number of nodes in the network.

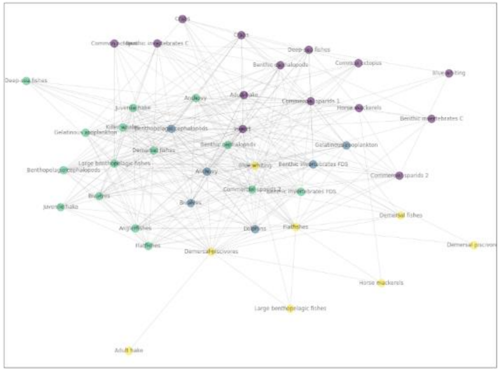
# Community detection analysis



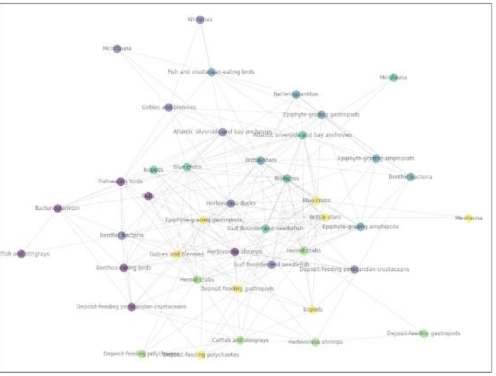
FW_002 with total 14 species



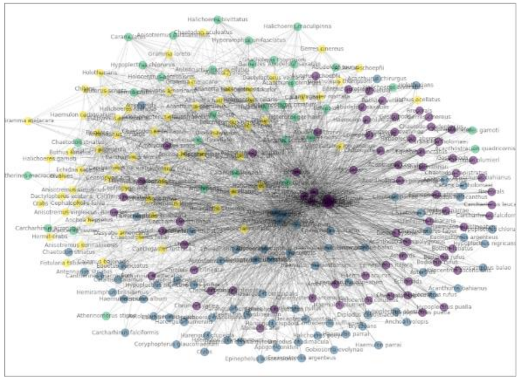
FW_003 with total 28 species



FW_005 with total 44 species



FW_007 with total 48 species



FW_008 with total 249 species

- Don’t get a clear distinction between each group.
- Many groups are evenly distributed in all the communities as the network goes large.
- Roles of these species in the carbon exchange cannot be derived from the traditional divisions in a trivial manner.

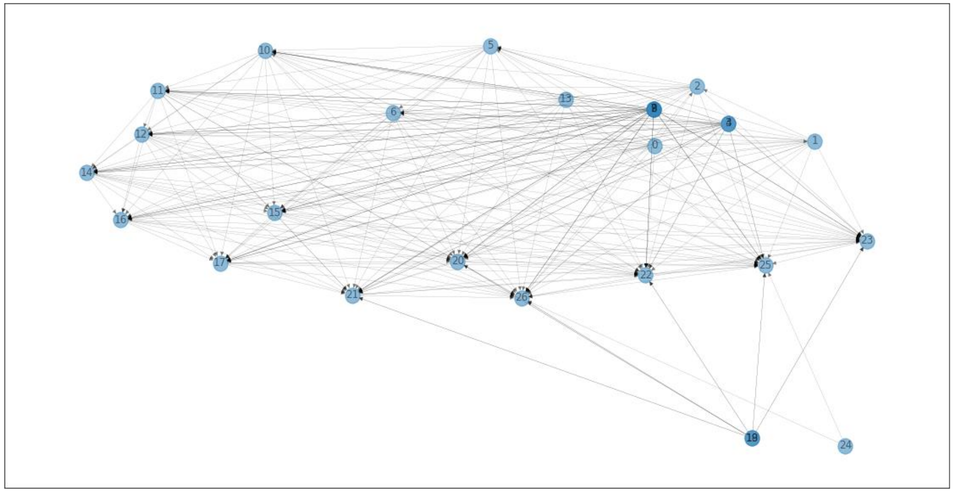
# Ecological models: cascade matrix

<u>Cascade Model (Cohen & Newman 1985):</u>

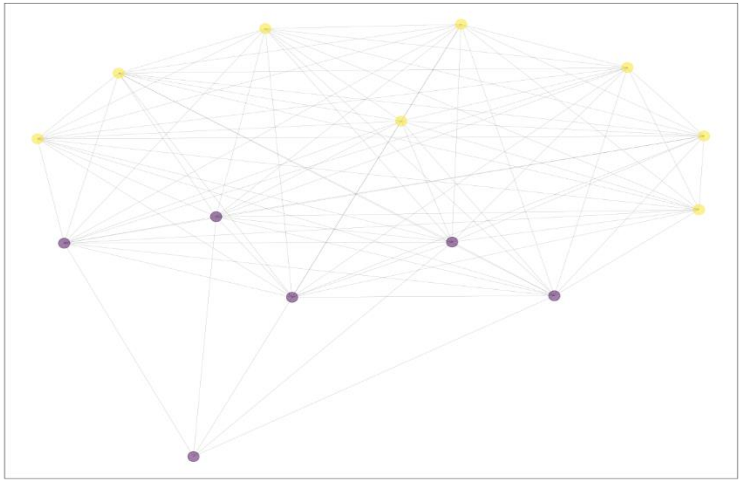
- Each species has a fixed probability of preying upon the preceding species.
- Species with highest ranking functions as a top predator, while that with the lowest ranking as a producer.

<u>Build Cascade model:</u>

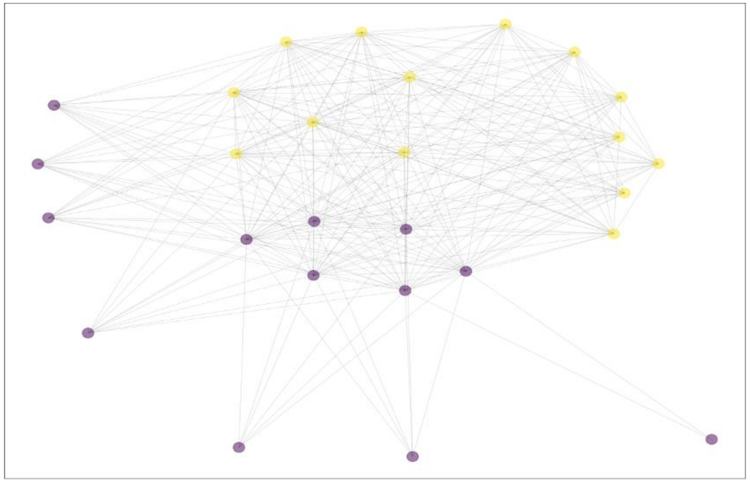
- Assigns each species a random value drawn uniformly from the interval [0, 1].
- Two Parameters: S (species richness) and C (connectance).
- Each species has probability **P = 2CS/(S-1)** of consuming only species with values less than its own.



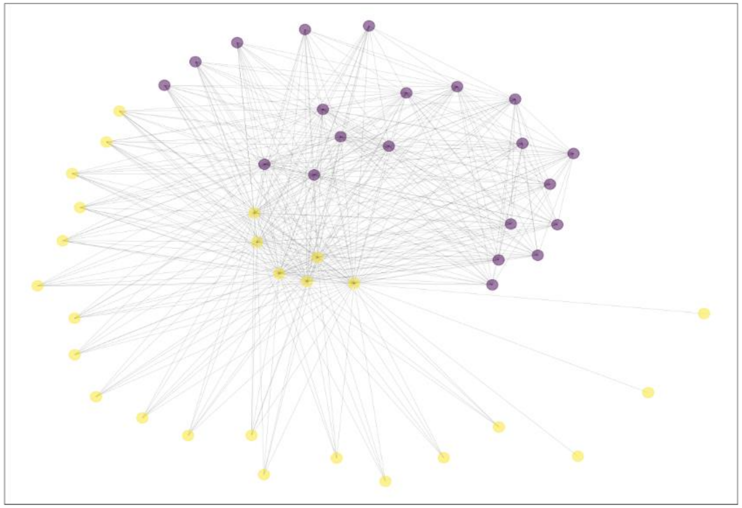
# Ecological models: cascade matrix



FW_002 with total 14 species



FW_003 with total 28 species



FW_007 with total 48 species

- Cascade model create an order of hierarch (the top species predates almost every other specie).
- Predict the community and the network well with small no species network.
- Predict the community and the network bad with big no species network.

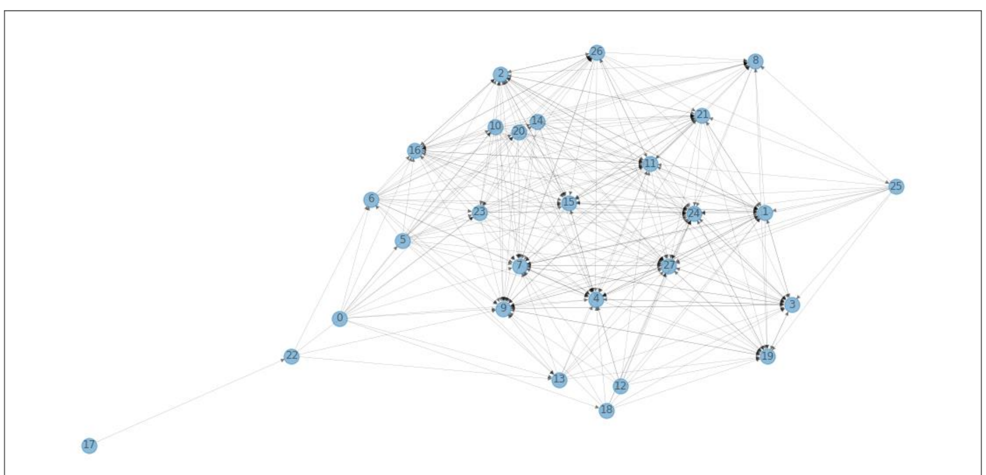
# Ecological models: niche matrix

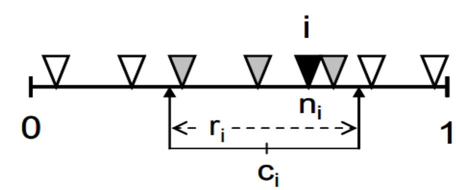
Niche model (William & Martinez 2000):

- The niche model similarly assigns each species a randomly drawn "niche value".
- The species are then constrained to consume all prey species within one range of values whose randomly chosen center is less than the consumer's niche value.

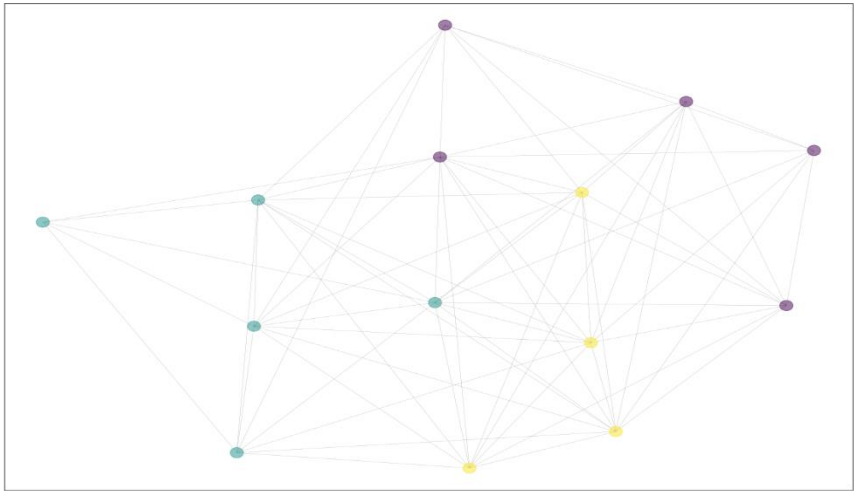
Build Cascade model:

- Each of S species is assigned a 'niche value' parameter $v_i$ drawn from [0, 1].
- Species i consumes all species falling in a range $r_i$ that is placed by uniformly drawing the center of the range $c_i$ from $[n_i$, 1-$r_i$/2].
- The size of $r_i$ is assigned by using a beta function to randomly draw values from [0, 1].

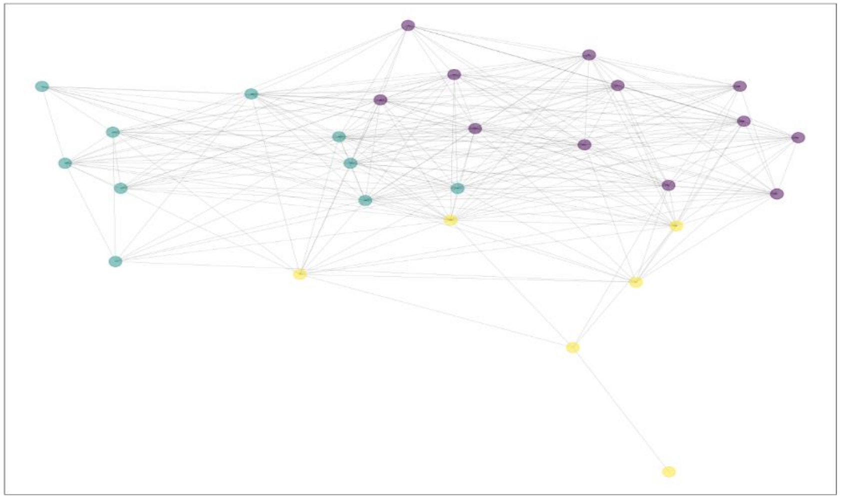




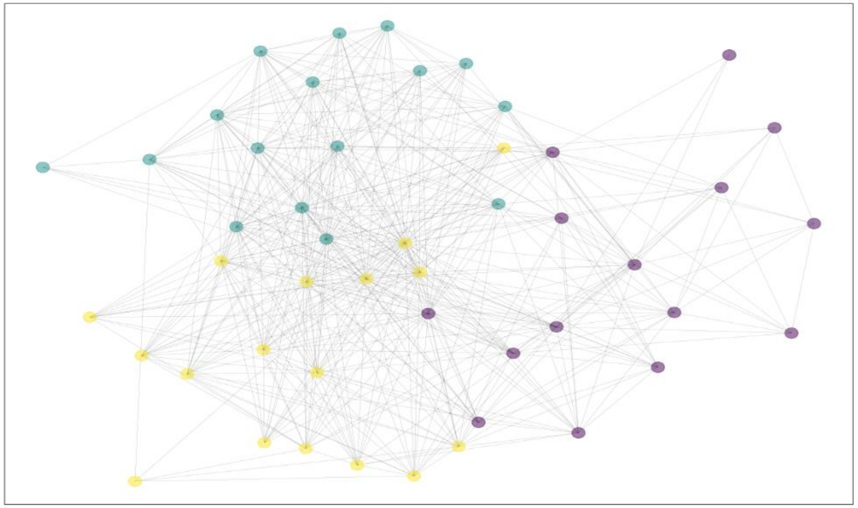
# Ecological models: niche matrix



FW_002 with total 14 species



FW_003 with total 28 species



FW_006 with total 48 species

- Niche model organizes the network in slightly interacting group.
- Reproduce the variety of connections inside the same niche as in a real FW.
- Predict the community and the network well with both big and small no species network.

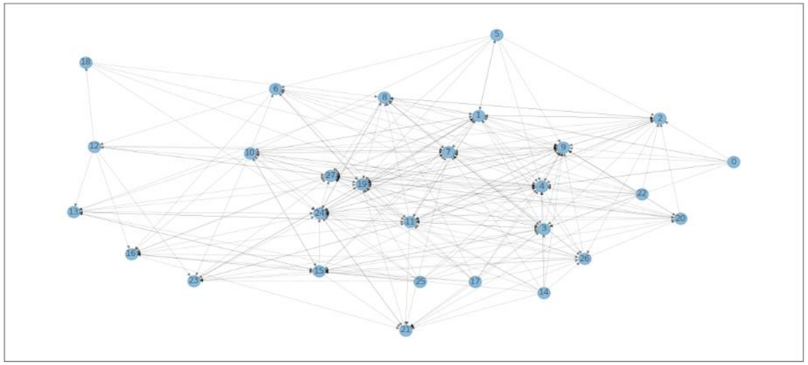
# Ecological models: nested matrix

Nested-Hierarchy Model (Cattin et al. 2004):

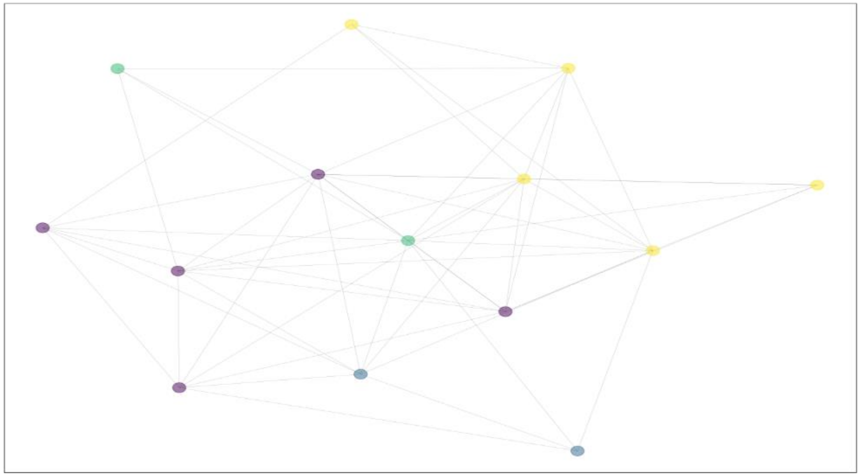
- Gives each species a niche value and a range, exactly as in the Niche Model.
- Instead of establishing links directly to species within the range, first the number of prey to be consumed by each species is determined.

Build Nested-Hierarchy model:

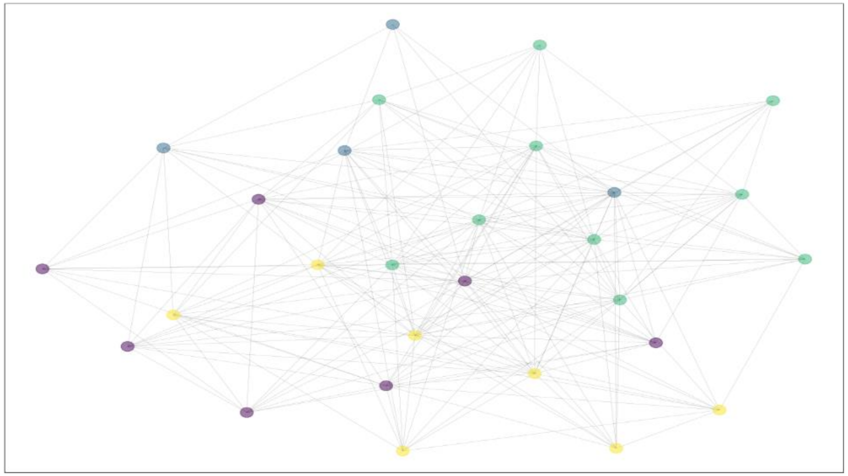
- Each consumer i's number of resource species j assigned using beta distribution.
- Resources j chosen randomly from species with $n_j < n_i$ until all links are assigned or a j is obtained which already has at least one consumer.
- Species i links to j and joins j's "consumer group".
- Subsequent j chosen from remaining species with no consumers and $n_j < n_i$.
- Subsequent j chosen randomly from species with $n_j \geq n_i$.



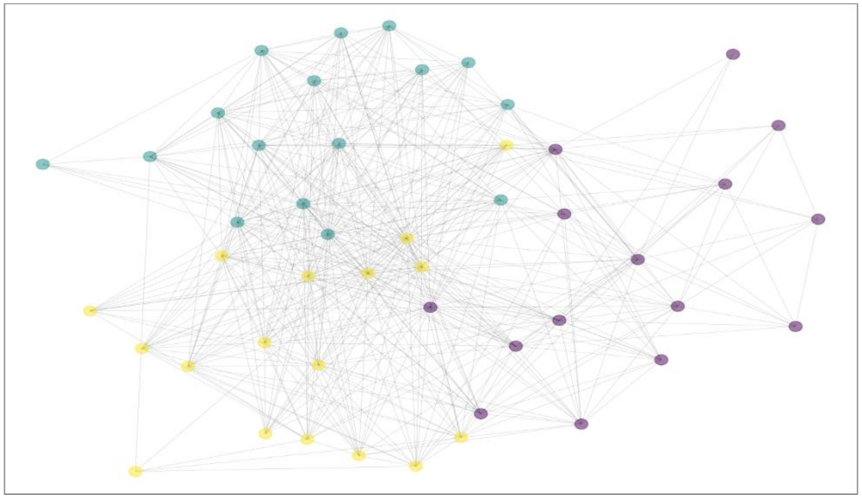
# Ecological models: nested matrix



FW_002 with total 14 species



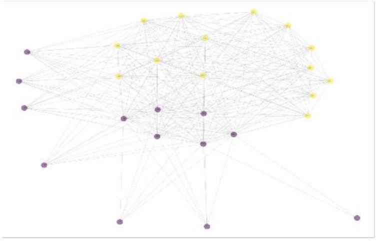
FW_003 with total 28 species



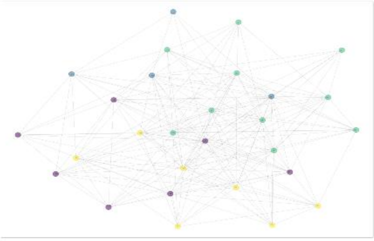
FW_006 with total 48 species

- Similar to Niche.
- Forms the number of species in the group and it gives a clear distinction between each group through community detection.
- Predict the community and the network well with both big and small no species network.

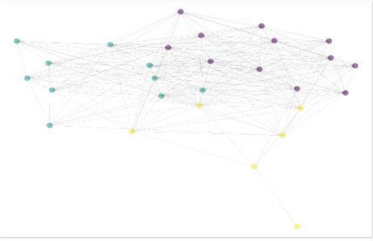
# Empirical network vs model network



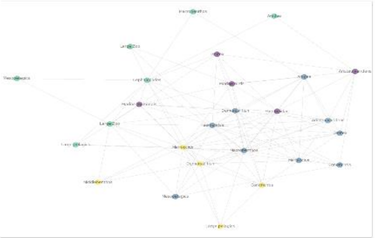
Cascade model FW_003



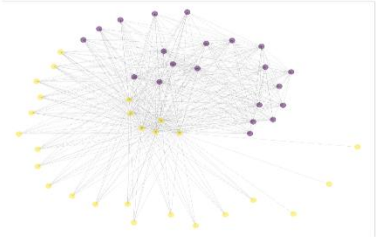
Niche model FW_003



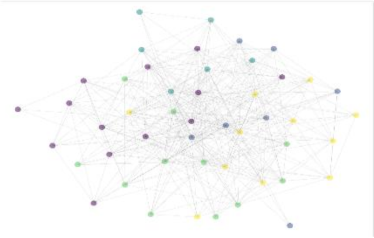
Nested model FW_003



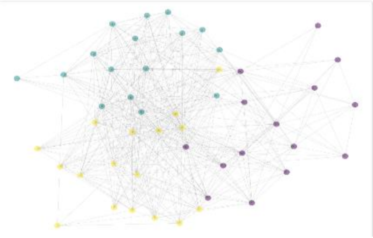
Real FW_003



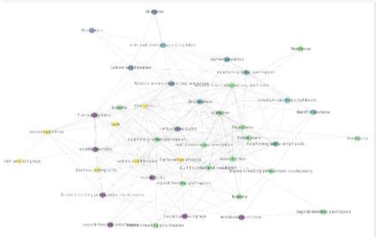
Cascade model FW_007



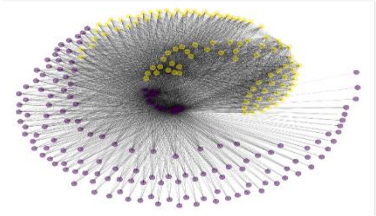
Niche model FW_007



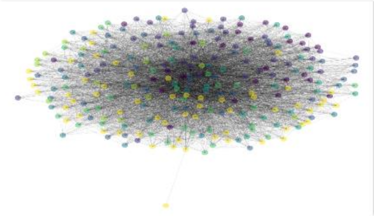
Nested model FW_007



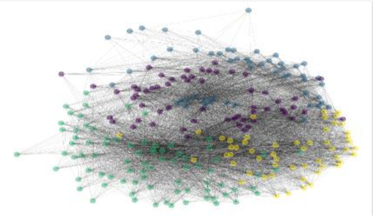
Real FW_007



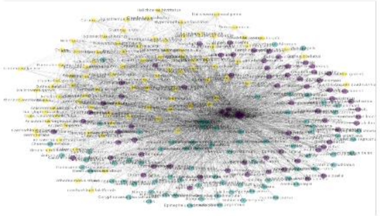
Cascade model FW_008



Niche model FW_008



Nested model FW_008



Real FW_008

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# Thanks for the attention