Modularity in plant-pollinator networks

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Introduction

- Modularity = “clumping”
  - Modules = proportionally link-dense subgroups
  - Breaks down the network into structural parts
  - Modularity vs. number of modules

Binary approach

Weighted approach

Research questions

1. How modular are the networks?
2. How does observed network modularity differ from a null (random network) model?
3. How does modularity vary between years?
4. How does modularity relate to phylogenetic distance?
Methods: Data used

- Four network groupings
  - 2016
  - 2015
  - 2011-14
  - All years
- All meadows, all watches
Methods: Estimating modularity

- DIRTLPAwb+ (Beckett 2016)
  - Stochastic optimization algorithm - 20 trials
- null model distribution
  - 20 null networks, 10 trials each

Each null model is randomly generated, and matches the observed network in the following ways:

**Link density**: number of links per species

**Size**: number of nodes

**Connectance**: proportion of realized links
## Results: Network modularity

DIRTLPawb+ modularity (best of 20 trials)

<table>
<thead>
<tr>
<th>year (s)</th>
<th>weighted</th>
<th></th>
<th>binary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>modularity</td>
<td># of modules</td>
<td>modularity</td>
<td># of modules</td>
</tr>
<tr>
<td>2016</td>
<td>0.224</td>
<td>5</td>
<td>0.311</td>
<td>5</td>
</tr>
<tr>
<td>2015</td>
<td>0.0939</td>
<td>5</td>
<td>0.315</td>
<td>5</td>
</tr>
<tr>
<td>2011-14</td>
<td>0.195</td>
<td>4</td>
<td>0.209</td>
<td>4</td>
</tr>
<tr>
<td>ALL</td>
<td>0.177</td>
<td>4</td>
<td>0.218</td>
<td>4</td>
</tr>
<tr>
<td>Other networks (averages)</td>
<td>0.473</td>
<td>7.3</td>
<td>.459</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Our networks

DIRTLPawb+ modularity results for 23 observed ecological networks (Beckett 2016)
Weighted network modularity compared to a null distribution

Histogram of Modularity_2016

Histogram of Modularity_2015

Histogram of Modularity_2011_14

Histogram of Modularity_ALL
Binary network modularity compared to a null distribution

Histogram of Modularity_2016

Histogram of Modularity_2015

Histogram of Modularity_2011_14

Histogram of Modularity_ALL
Results: Network modularity

Z scores for modularity compared to null distribution

Z score (absolute value)

2016 2015 2011-14 ALL

2016 2015 2011-14 ALL

Absolute modularity

Modularity

weighted

binary
P-values for number of modules

Observed number of modules lower than expected
Methods:

Phylogenetic distance

- Phylogenetic distance as defined by J. Huestis
  - average pairwise within-module phylogenetic distance
  - compared to a null grouping
    - A different partition of the same network – same number of modules, with nodes assigned randomly to a module
Within-module phylogenetic distance between plants

p values

<table>
<thead>
<tr>
<th></th>
<th>weighted</th>
<th>binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>0.221627</td>
<td>0.3008749</td>
</tr>
<tr>
<td>2015</td>
<td>0.4001985</td>
<td>0.02933728</td>
</tr>
<tr>
<td>2011-14</td>
<td>0.4113134</td>
<td>0.06483319</td>
</tr>
<tr>
<td>ALL</td>
<td>0.1367469</td>
<td>0.08427214</td>
</tr>
</tbody>
</table>
Results: Summary

1. How modular are the networks? What results show this?
   The weighted networks are modular – results > 0, but much less modular than would be expected.

2. How does observed modularity differ from a null (random network) model?
   Observed modularity was significantly lower than the null model distribution (p values close to zero) for both weighted and binary networks.

2. Does modularity vary between years?
   Weighted modularity does vary considerably between years, but binary modularity is relatively consistent.

3. How does modularity relate to phylogenetic relatedness?
   For the weighted networks, within-module phylogenetic relatedness scores fell within what could be predicted by the null model. The binary network, for one year, had a modularity score that was higher than what would be predicted, with p-value < .05.
Discussion

• Why is modularity low?
Modularity may not be the defining network structure for these communities. Generalists dominate over specialists
• Why might modularity values vary between years?
Variation in populations of generalist vs. specialist species. Inconsistency in data collection
• Why are values from binary different than weighted?
Emphasis on super pollinators and super generalists (apis, bombus, eristalis)
• Why is modularity related (or not) to phylogenetic distance between plants?
Modularity could be driven by other factors. Traits, morphology, coevolution.
Conclusions

• Modularity was extremely low in observed networks
• Binary and weighted approaches are different, and should be used with the appropriate intention
• Modularity is not strongly driven by phylogenetic relatedness of plants

• Further research
  o Phylogenetic relatedness of pollinators
  o Trait analysis
  o Comparison of module members in binary and weighted networks
  o Module member analysis
  o Properties of a meadow that might influence modularity – moisture, size, heterogeneity
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References

• Beckett SJ. 2016 Improved community detection in weighted bipartite networks. R. Soc. open sci. 3: 140536


Questions?

Oregon State University

HJ Andrews Experimental Forest

Goshen College