DETAILED REPORT OF WEIGHTED ANALYSES

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Contents

1. Dataset

We searched for weighted versions of the networks included in the binary dataset (see Appendix S1) in two online databases: the Web-of-life (http://www.web-of-life.es/) and the Interaction Web Database (http://www.ecologia.ib.usp.br/iwdb/), and in a pool of weighted host-parasite networks (Hadfield et al., 2009) directly provided by Boris Krasnov.

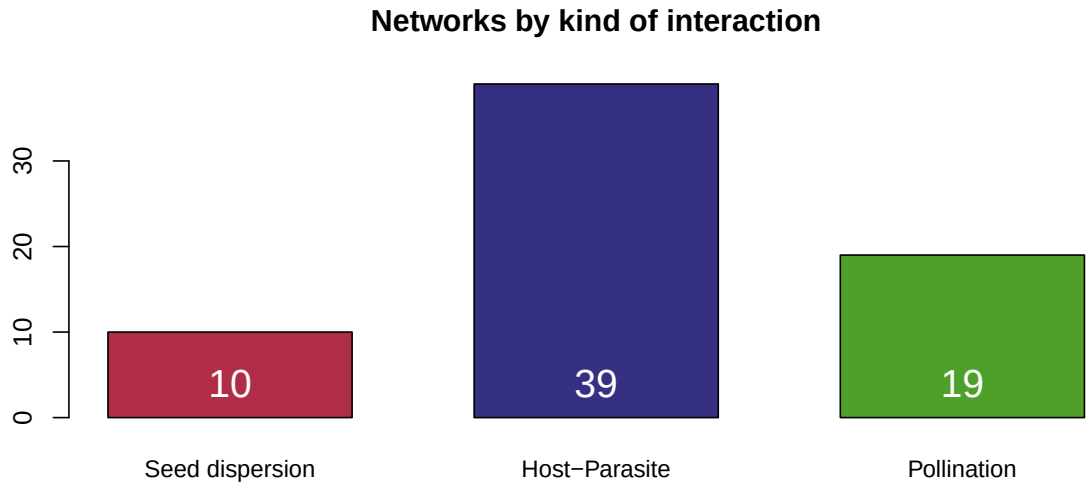
```
## [1] "CODES: set1W"
```

ID	Interaction	References	rows	cols	connectance
TP-001	disp	Beehler 1983	31	9	0.427
TP-002	disp	Sorensen 1981	14	11	0.299

ID	Interaction	References	rows	cols	connectance
TP-003	disp	Frost 1980	16	10	0.688
TP-005	disp	Galetti 1996	7	18	0.302
TP-006	disp	Galetti 1996	35	29	0.144
TP-008	disp	Snow 1988	19	29	0.383
TP-010	disp	Noma 1997	15	8	0.317
TP-013	disp	Snow 1971	50	14	0.334
TP-014	disp	Jordano unpub	25	33	0.182
TP-020	pollin	Elberling 1999	118	23	0.088
TP-025	pollin	Inoue 1990	883	114	0.019
TP-026	pollin	Inouye 1988	85	40	0.078
TP-027	pollin	Kakutani 1990	318	113	0.022
TP-028	pollin	Kato 1996	195	64	0.035
TP-029	pollin	Kato 1990	678	89	0.020
TP-030	pollin	Kato 1993	365	91	0.026
TP-033	pollin	Mosquin 1967	18	11	0.192
TP-038	pollin	Olesen 2002	12	10	0.250
TP-045	pollin	Schemske 1978	32	7	0.263
TP-046	disp	Baird 1980	21	7	0.340
TP-079	pollin	VÃ¡zquez 2002	90	14	0.130
TP-081	pollin	Ingversen 2006	29	43	0.091
TP-084	pollin	Helenurm 1987	102	12	0.136
TP-085	pollin	Memmott 1999	79	25	0.151
TP-086	pollin	Ingversen 2006	43	31	0.109
TP-091	pollin	Lundgren 2005	26	17	0.143
TP-096	paras	Alania 1964	20	15	0.247
TP-097	paras	Arthur 1976	29	7	0.384
TP-098	paras	Mikulin 1959	26	19	0.217
TP-099	paras	Vershinina 1967	17	29	0.191
TP-100	paras	deMoraes 2003	10	16	0.238
TP-101	paras	Linsdale 1956	22	19	0.230
TP-102	paras	Davis 2002	17	9	0.268
TP-103	paras	Elshanskaya 1972	18	9	0.278
TP-104	paras	Leong 1981	40	10	0.228
TP-105	paras	Burdelova 1996	22	15	0.303
TP-106	paras	Mikulin 1959	37	22	0.130
TP-107	paras	Morozkina 1971	25	8	0.340
TP-108	paras	Allred 1968	29	14	0.155
TP-109	paras	Syrvacheva 1964	21	13	0.293
TP-110	paras	Koshkin 1966	22	9	0.303
TP-111	paras	Leonov 1958	12	8	0.406
TP-112	paras	Reshetnikova 1959	19	17	0.232
TP-113	paras	Arai 1983	51	14	0.160
TP-114	paras	Vasiliev 1966	21	10	0.219
TP-115	paras	Labunets 1967	44	21	0.150
TP-116	paras	Popova 1968	31	18	0.201
TP-117	paras	Krasnov 1997	13	13	0.219
TP-118	paras	Morlan 1955	34	29	0.109
TP-119	paras	Yudin 1976	16	15	0.225
TP-120	paras	Shwartz 1958	35	16	0.146
TP-121	paras	Violovich 1969	34	27	0.195
TP-122	paras	Sineltschikov 1956	53	17	0.175
TP-123	paras	Vasiliev 1966	14	16	0.170

ID	Interaction	References	rows	cols	connectance
TP-124	paras	Bangham 1955	97	33	0.099
TP-125	paras	Pauller 1966	13	10	0.262
TP-126	paras	Stanko 2002	22	19	0.230
TP-127	paras	Chinniah 1978	25	6	0.353
TP-128	paras	Kunitsky 1962	23	13	0.204
TP-129	paras	Mikulin 1958	35	23	0.108
TP-130	paras	Zagniborodova 1960	42	18	0.290
TP-131	paras	Letov 1966	28	13	0.327
TP-132	paras	Kozlovskaya 1958	21	9	0.360
TP-133	paras	Nazarova 1981	35	29	0.239
TP-134	paras	Emelyanova 1967	29	15	0.320
TP-135	pollin	Motten 1986	44	13	0.250
TP-138	pollin	Small 1976	34	13	0.319
TP-139	pollin	Ollerton 2003	56	9	0.204

```
## [1] "Weighted networks in the dataset: 68"
```



1.1. Warnings (matrix loadings)

Warnings for missing rows and columns in the weighted matrix.

Inconsistencies for the number of rows and columns between the binary and weighted matrices.

Inconsistencies within 2 decimal places for connectance.

```
## [1] "weighted TP-002 had 1 empty columns"
## [1] "TP-002   Rows in binary matrix: 7  Rows in weighted matrix:  14"
## [1] "TP-002   Cols in binary matrix: 6  Cols in weighted matrix:  11"
## [1] "TP-002   Connectance in binary matrix: 0.52 Connectance in weighted matrix: 0.3"
## [1] "weighted TP-008 had 1 empty rows"
## [1] "weighted TP-008 had 6 empty columns"
## [1] "TP-008   Rows in binary matrix: 11  Rows in weighted matrix:  19"
```

```
## [1] "TP-008   Cols in binary matrix: 14  Cols in weighted matrix:  29"
## [1] "TP-008   Connectance in binary matrix: 0.31 Connectance in weighted matrix: 0.38"
## [1] "TP-014   Connectance in binary matrix: 0.19 Connectance in weighted matrix: 0.18"
## [1] "TP-025   Rows in binary matrix: 840  Rows in weighted matrix:  883"
## [1] "TP-025   Cols in binary matrix: 112  Cols in weighted matrix:  114"
## [1] "TP-026   Rows in binary matrix: 91  Rows in weighted matrix:  85"
## [1] "TP-026   Cols in binary matrix: 41  Cols in weighted matrix:  40"
## [1] "TP-027   Rows in binary matrix: 314  Rows in weighted matrix:  318"
## [1] "TP-028   Rows in binary matrix: 187  Rows in weighted matrix:  195"
## [1] "TP-028   Connectance in binary matrix: 0.04 Connectance in weighted matrix: 0.03"
## [1] "weighted TP-029 had 1 empty rows"
## [1] "weighted TP-029 had 2 empty columns"
## [1] "TP-029   Rows in binary matrix: 679  Rows in weighted matrix:  678"
## [1] "TP-029   Cols in binary matrix: 91  Cols in weighted matrix:  89"
## [1] "TP-030   Rows in binary matrix: 356  Rows in weighted matrix:  365"
## [1] "TP-030   Cols in binary matrix: 90  Cols in weighted matrix:  91"
## [1] "TP-045   Rows in binary matrix: 33  Rows in weighted matrix:  32"
## [1] "TP-045   Connectance in binary matrix: 0.28 Connectance in weighted matrix: 0.26"
## [1] "TP-081   Rows in binary matrix: 36  Rows in weighted matrix:  29"
## [1] "TP-081   Cols in binary matrix: 61  Cols in weighted matrix:  43"
## [1] "TP-081   Connectance in binary matrix: 0.08 Connectance in weighted matrix: 0.09"
## [1] "TP-086   Rows in binary matrix: 44  Rows in weighted matrix:  43"
## [1] "TP-099   Cols in binary matrix: 28  Cols in weighted matrix:  29"
## [1] "TP-099   Connectance in binary matrix: 0.2 Connectance in weighted matrix: 0.19"
## [1] "TP-103   Cols in binary matrix: 8  Cols in weighted matrix:  9"
## [1] "TP-103   Connectance in binary matrix: 0.3 Connectance in weighted matrix: 0.28"
## [1] "weighted TP-108 had 1 empty rows"
## [1] "weighted TP-111 had 1 empty rows"
## [1] "weighted TP-113 had 1 empty rows"
## [1] "TP-114   Cols in binary matrix: 9  Cols in weighted matrix:  10"
## [1] "TP-114   Connectance in binary matrix: 0.23 Connectance in weighted matrix: 0.22"
## [1] "TP-117   Rows in binary matrix: 11  Rows in weighted matrix:  13"
## [1] "TP-117   Connectance in binary matrix: 0.24 Connectance in weighted matrix: 0.22"
## [1] "weighted TP-121 had 1 empty rows"
## [1] "TP-125   Cols in binary matrix: 9  Cols in weighted matrix:  10"
## [1] "TP-125   Connectance in binary matrix: 0.28 Connectance in weighted matrix: 0.26"
## [1] "TP-126   Cols in binary matrix: 17  Cols in weighted matrix:  19"
## [1] "TP-126   Connectance in binary matrix: 0.25 Connectance in weighted matrix: 0.23"
## [1] "weighted TP-128 had 1 empty rows"
## [1] "weighted TP-133 had 1 empty rows"
```

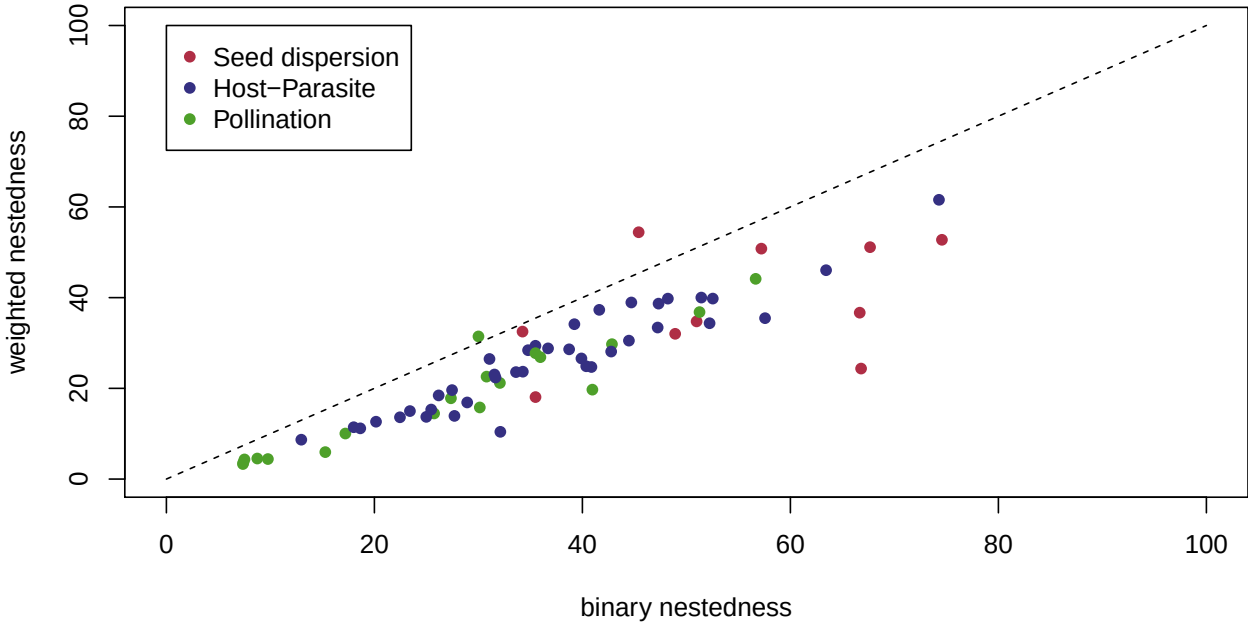
Networks with non integer cell values (= host-endoparasite networks with prevalence) were rounded to 1 decimal place and then multiplied by 10.

```
## [1] "TP-097 has non integer values"
## [1] "TP-097 rounded with 1 decimal place and multiplied by 10"
## [1] "Values < 0.1 converted to 0.1 before this procedure"
## [1] "TP-099 has non integer values"
## [1] "TP-099 rounded with 1 decimal place and multiplied by 10"
## [1] "Values < 0.1 converted to 0.1 before this procedure"
## [1] "TP-104 has non integer values"
## [1] "TP-104 rounded with 1 decimal place and multiplied by 10"
## [1] "Values < 0.1 converted to 0.1 before this procedure"
## [1] "TP-113 has non integer values"
## [1] "TP-113 rounded with 1 decimal place and multiplied by 10"
```

```
## [1] "Values < 0.1 converted to 0.1 before this procedure"
## [1] "TP-122 has non integer values"
## [1] "TP-122 rounded with 1 decimal place and multiplied by 10"
## [1] "Values < 0.1 converted to 0.1 before this procedure"
## [1] "TP-124 has non integer values"
## [1] "TP-124 rounded with 1 decimal place and multiplied by 10"
## [1] "Values < 0.1 converted to 0.1 before this procedure"
```

2. Binary vs. weighted indices (nestedness and modularity)

2.1. Correlation between binary nestedness (NODF) and weighted nestedness (WNODA):

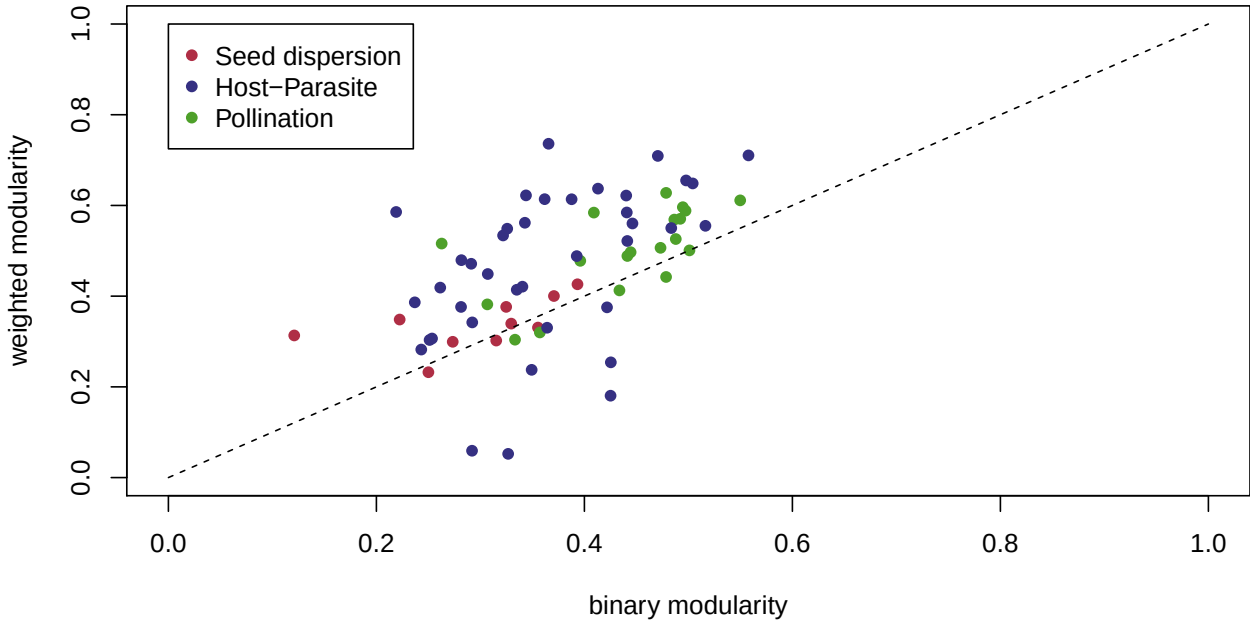



```
##
##  Spearman's rank correlation rho
##
## data:  TABLE_RESULTS$WNODA and BIN_TABLE_RESULTS$NODF
## S = 4584, p-value <2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##   rho
## 0.913
```

The dashed line represents equal values of weighted and binary nestedness. Most of the points (66 out of 68) are bellow the line, which means that networks are more nested in their binary than in their weighted structures.

The correlation between binary and weighted nestedness is very high.

2.2. Correlation between binary and weighted modularity:




```
##
##  Spearman's rank correlation rho
##
## data:  TABLE_RESULTS$modularity and BIN_TABLE_RESULTS$modularity
## S = 21542, p-value = 2e-07
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##   rho
## 0.589
```

The dashed line represents equal values of weighted and binary modularity. Most of the points (53 out of 68) are above the line, which means that networks are more modular in their weighted than in their binary structures.

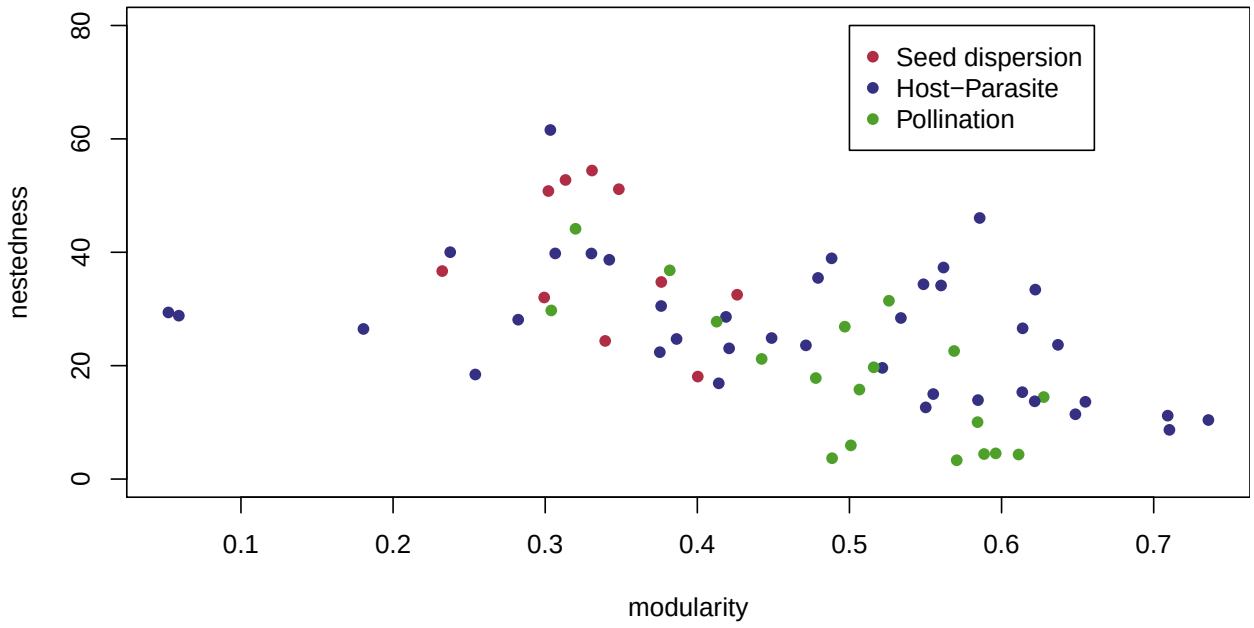
3. Nestedness vs. Modularity

Weighted nestedness: we applied the WNODA index (Pinheiro et al. 2019).

Weighted modularity: we calculated Barber's modularity index (Barber 2007) using the LPA and the DIRT LPA algorithms (Beckett 2016).

For too large networks (> 600 species), it was computational impracticable to apply the DIRT LPA algorithm, so we applied the faster, although a bit less effective, LPA.

ID	Interaction	References	rows	cols
TP-025	pollin	Inoue 1990	883	114
TP-029	pollin	Kato 1990	678	89

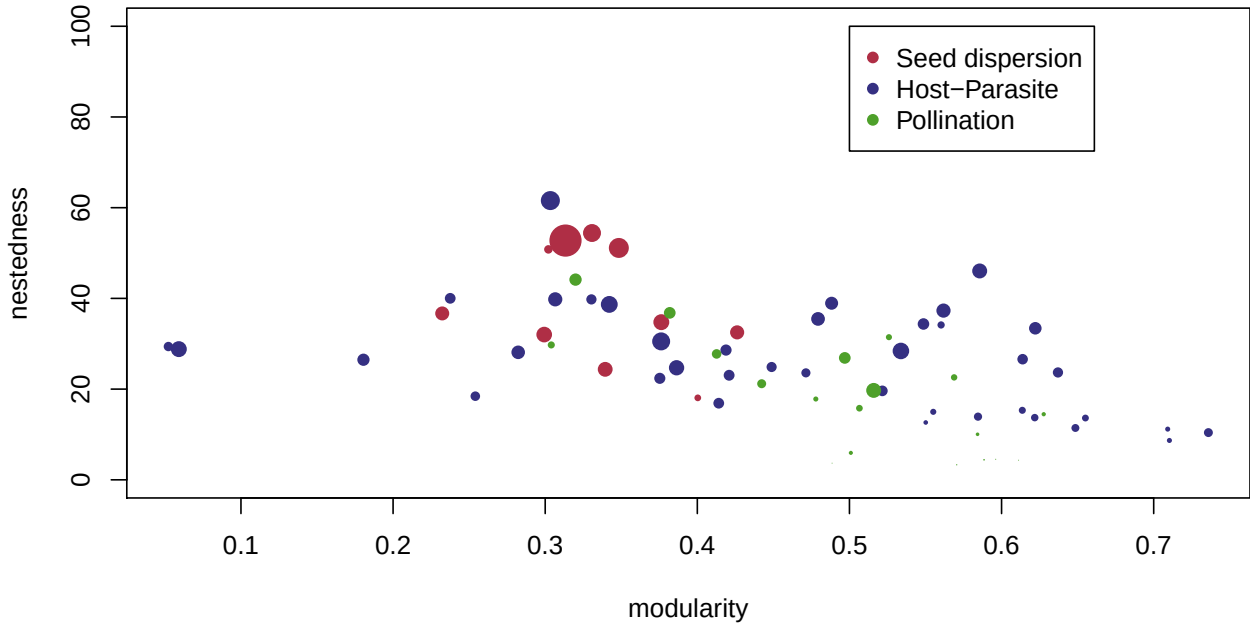


Testing the correlation between modularity and nestedness:

```
##
##  Spearman's rank correlation rho
##
## data:  TABLE_RESULTS$WNODA and TABLE_RESULTS$modularity
## S = 83820, p-value = 1e-07
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##  rho
## -0.6
```

4. Correlations and comparisons

4.1. Connectance:



Correlation between modularity and connectance:

```
## Warning in cor.test.default(TABLE_RESULTS$modularity,
## TABLE_RESULTS$connectance, : Cannot compute exact p-value with ties
```

```
##
##  Spearman's rank correlation rho
##
## data:  TABLE_RESULTS$modularity and TABLE_RESULTS$connectance
## S = 80923, p-value = 2e-06
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##    rho
## -0.545
```

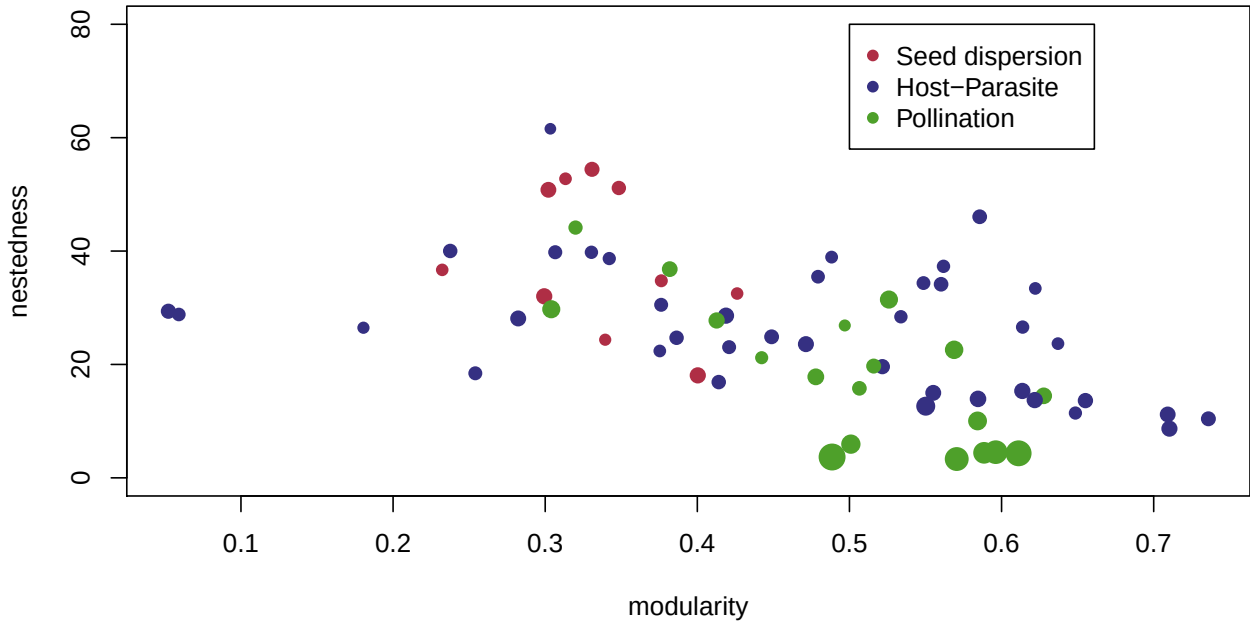
Correlation between nestedness and connectance:

```
## Warning in cor.test.default(TABLE_RESULTS$WNODA, TABLE_RESULTS$connectance, :
## Cannot compute exact p-value with ties
```

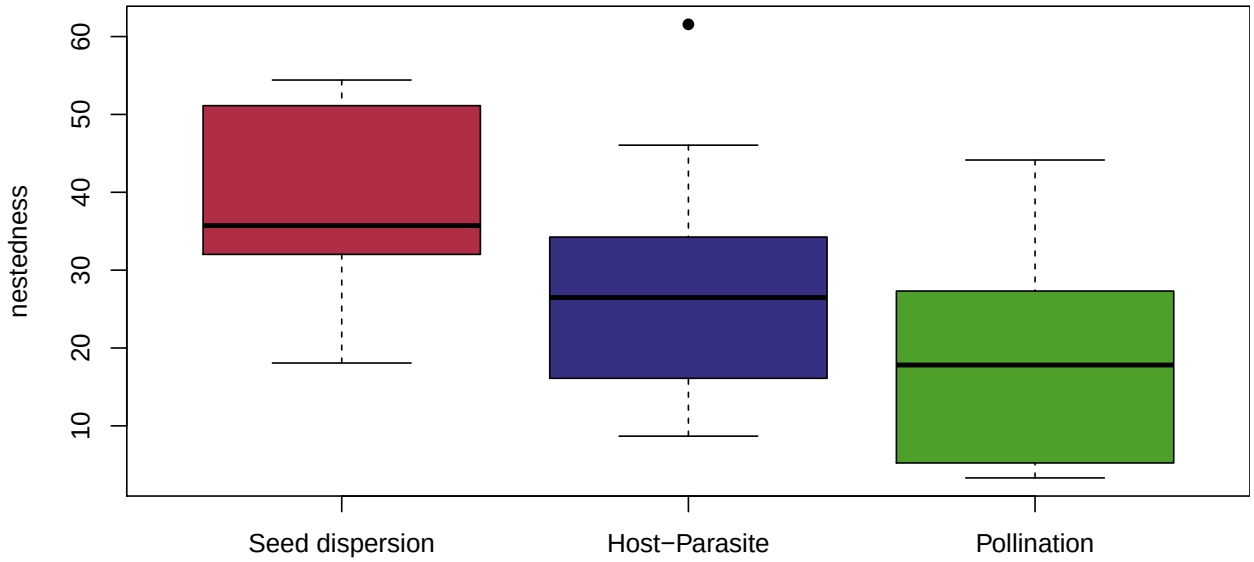
```
##
##  Spearman's rank correlation rho
##
## data:  TABLE_RESULTS$WNODA and TABLE_RESULTS$connectance
## S = 11778, p-value = 9e-15
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##   rho
## 0.775
```

4.2. Network size:

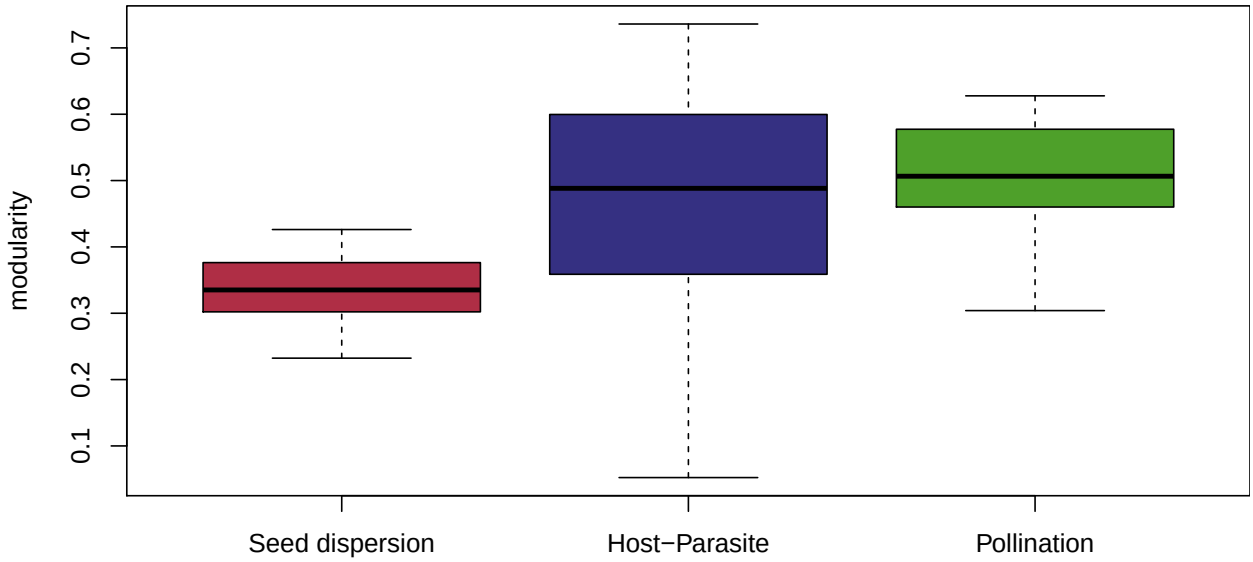
Size was log transformed (size = log(number of species))



4.3. Nestedness vs. kind of interaction



4.4. Modularity vs. kind of interaction



5. Modularity and nestedness significance

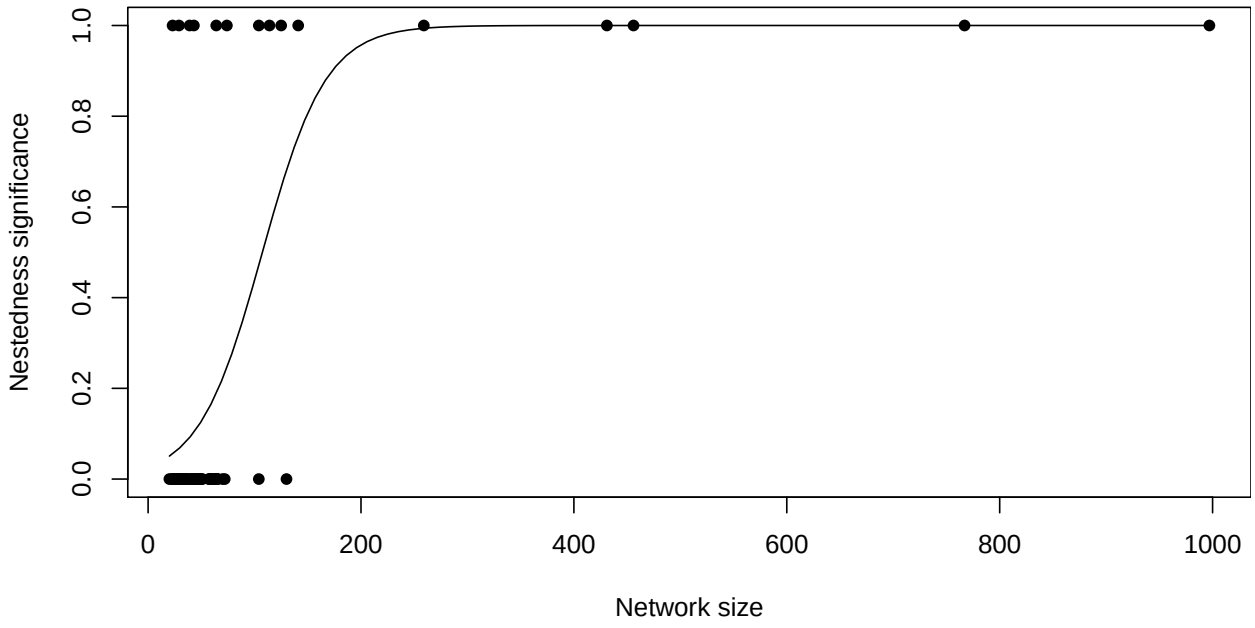
Null models in our study are composed of 105 randomized matrices each. This is not a very high number of matrices, but for computational limitations it was impracticable to produce larger null models. We analyzed a large number of real networks (binary: 142, weighted: 68), some of which including a very large number of species (max= 1881 species).

All weighted networks have link density higher than 1.

5.1. Significantly nested

Nestedness significance was assessed through comparisons with the equiprobable null model.

```
## [1] "Networks with significant nestedness: 15"
```



5.2. Significantly modular

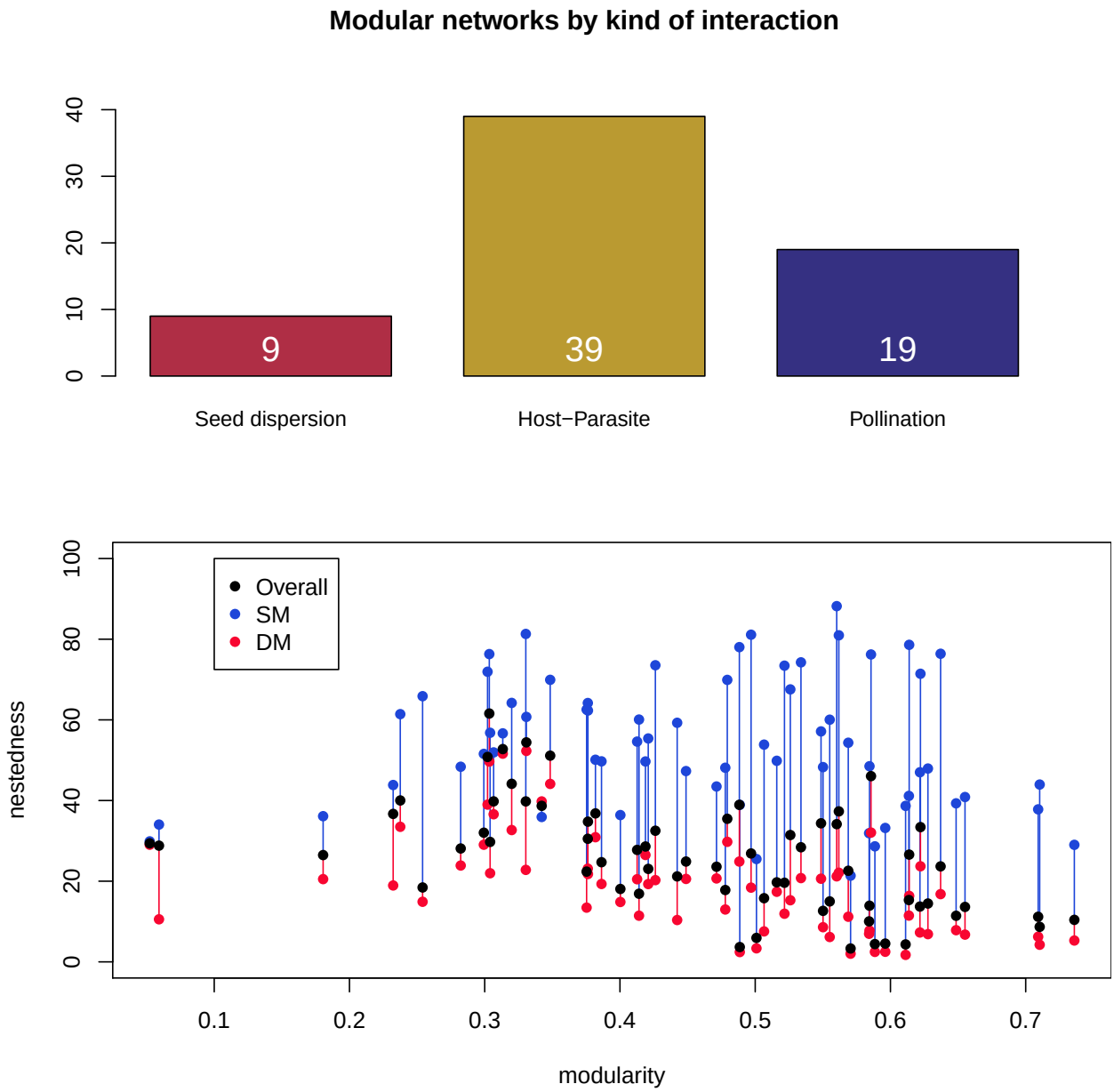
Modularity significance was assessed through comparisons with the proportional null model.

```
## [1] "Networks with significant modularity: 67"
```

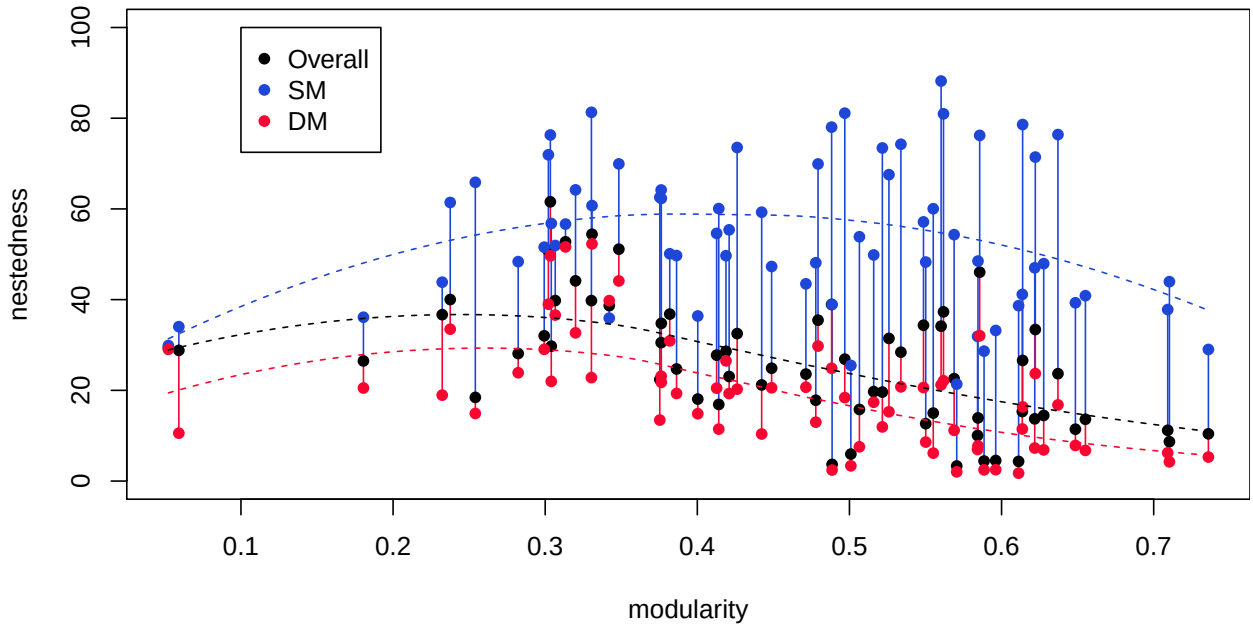
6. Nestedness SM and DM

For significant modular networks we calculated nestedness between species belonging to the same module (N_{SM}) and nestedness between species in different modules (N_{DM}) (Flores et al. 2013, Pinheiro et al. 2019, Felix et al. 2022).

```
## [1] "Modular networks: 67"
```



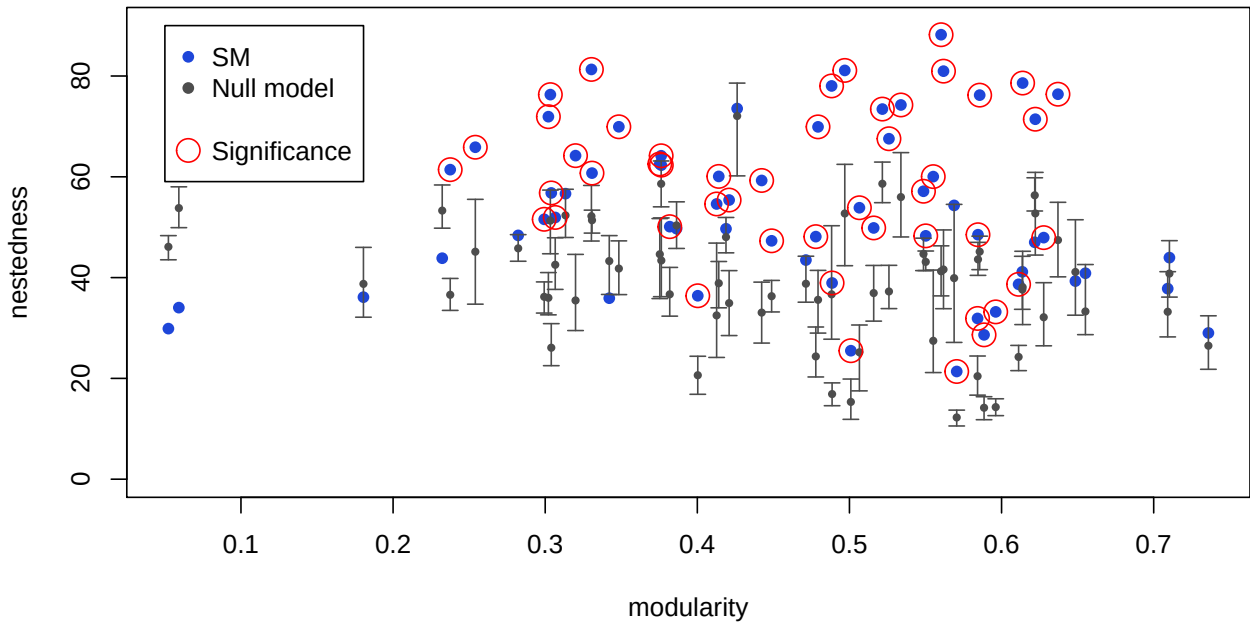
I applied local regressions (R function loess), very smoothly, to see the general trend of NODF_{O}, NODF_{SM} and NODF_{DM}, with increasing modularity.



7. Significance of nestedness SM

We used restricted null models (models that conserve the modular structure on the networks) to test N_{SM} significance.

```
## [1] "Networks with significant nestedness SM: 48"
```



8. Network topologies

Significance tests:

Equiprobable null model for N_O significance.

Proportional null model for modularity significance.

Equiprobable restricted null model for N_{SM} significance.

Topologies:

Nested network: non-significant modularity and significant N_O

Pure modular network: significant modularity and non-significant N_{SM}

Compound topology: singnificant modularity and significant N_{SM}

Unstructured: non significant N_O and non significant modularity

topology	Number of networks
nested	1
pure modular	19
compound	48

8.1. Topology vs. kind of interaction

	seed dispersal	host-parasite	pollination
nested	1	0	0
pure modular	3	15	1
compound	6	24	18

9. References

C. O. Flores, S. Valverde, J. S. Weitz, Multi-scale structure and geographic drivers of cross-infection within marine bacteria and phages. ISME J. 7, 520–532 (2013).

J. D. Hadfield, B. R. Krasnov, R. Poulin, S. Nakagawa, A Tale of Two Phylogenies: Comparative Analyses of Ecological Interactions. Am. Nat. 183, 174–187 (2014).

S. J. Beckett, Improved community detection in weighted bipartite networks. R. Soc. Open Sci. 3, 140536 (2016).

R. B. P. Pinheiro, G. M. F. Felix, C. F. Dormann, M. A. R. Mello, A new model explaining the origin of different topologies in interaction networks. Ecology 100, 1–30 (2019).

G. M. Felix, R. B. P. Pinheiro, R. Poulin, B. R. Krasnov, M. A. R. Mello, The compound topology of host–parasite networks is explained by the integrative hypothesis of specialization. Oikos 2022 (2022).