Pottery decor as networks on the Middle Niger

10 Juni, 2024

Abstract

This paper reports on an attempt to analyse decorative techniques on archaeological pottery from the Middle Niger as knowledge exchange networks. The 12th-century CE state of this network is modelled and analysed, and then compared to its 9th-century counterpart. The analysis shows how knowledge about pottery decoration was propagated within networks of different sizes and intensities, from local, well-connected networks to more loosely tied long-distance connections. The article shows how the perspective of network analysis differs from, and can fruitfully complement, previous treatments of ceramic décor distribution in the region. It adds a novel perspective to what the distribution of archaeological ceramics in this region reflects, and contributes to the generation of hypotheses that can be further tested by fieldwork.

Keywords: Mali; network analysis; pottery; archaeological ceramics

The full text of the article is available in the published version in “Azania: archaeological research in Africa”. This document contains the code for all analyses and figures in the text,as well as some supplementary analyses and figures. It is structured by section to ease overview.

For details on the data and its preparation, see the document in the folder “analysis/supplementary\_materials”.

# 1 Introduction

## 1.1 Middle Niger Ceramics:

### 1.1.1 Lack of temporal markers:

### 1.1.2 Ceramics and social boundaries:

### 1.1.3 Ceramics as trade goods:

## 1.2 Ceramic decors as networks

# 2 Methods

## 2.1 Data

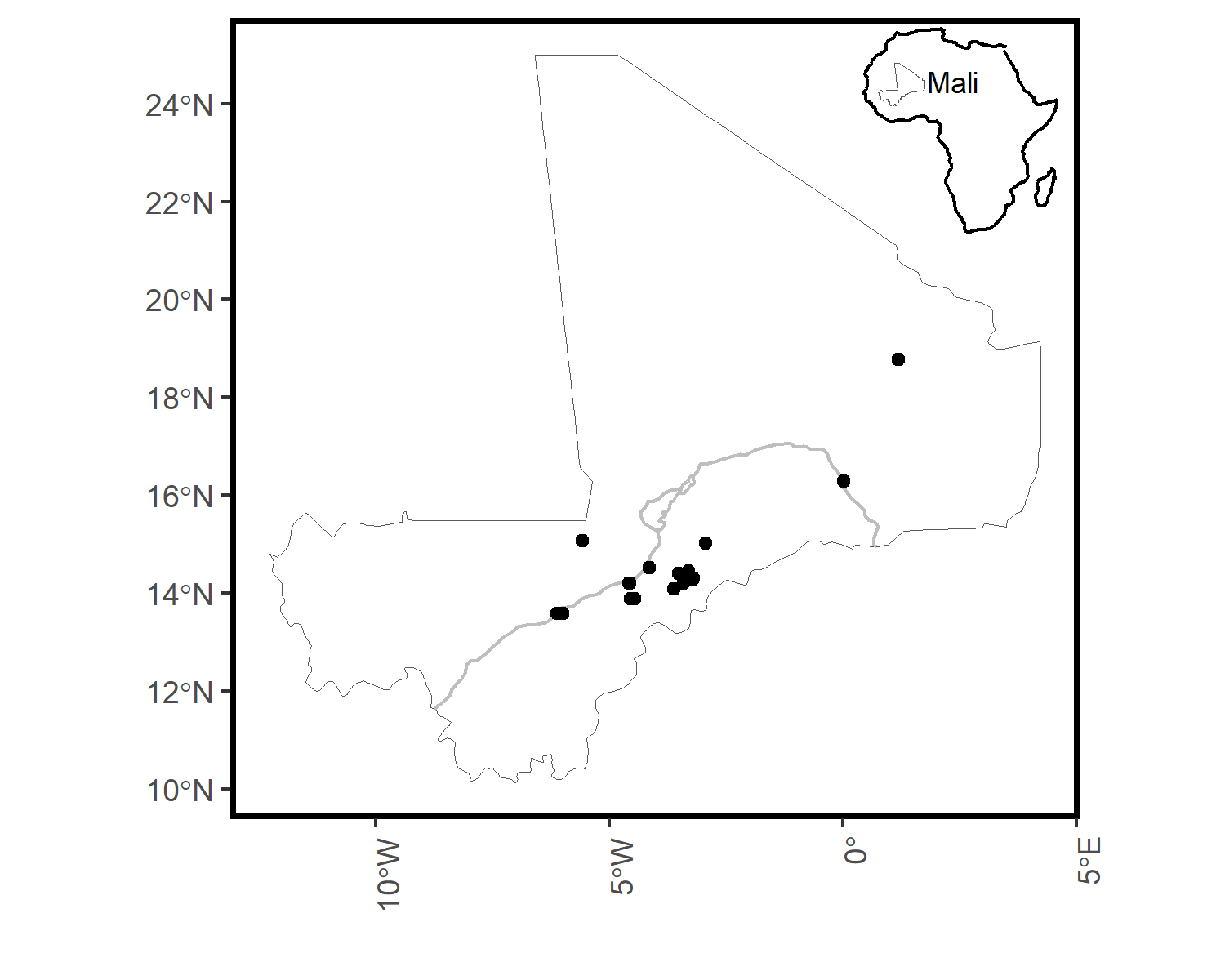


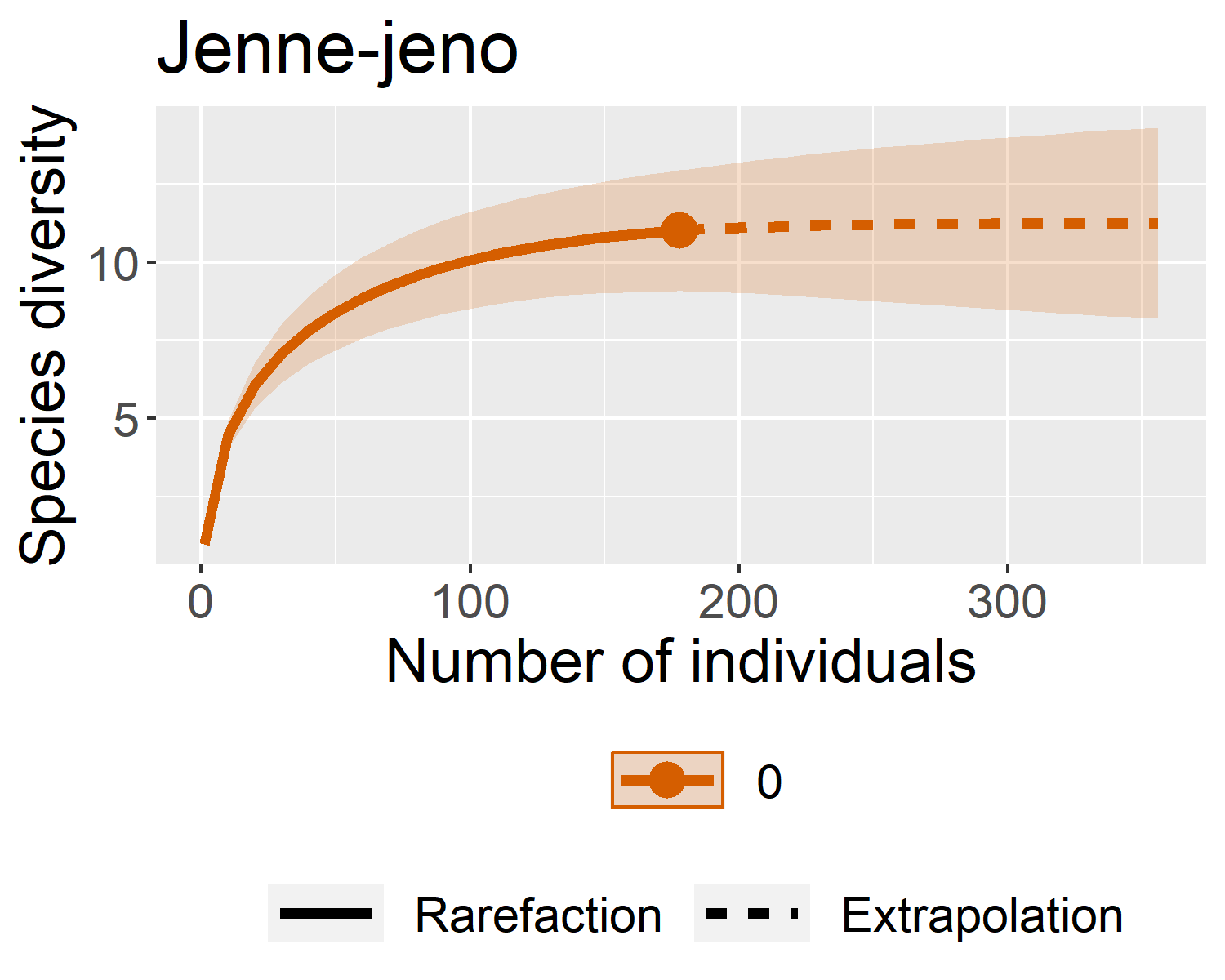
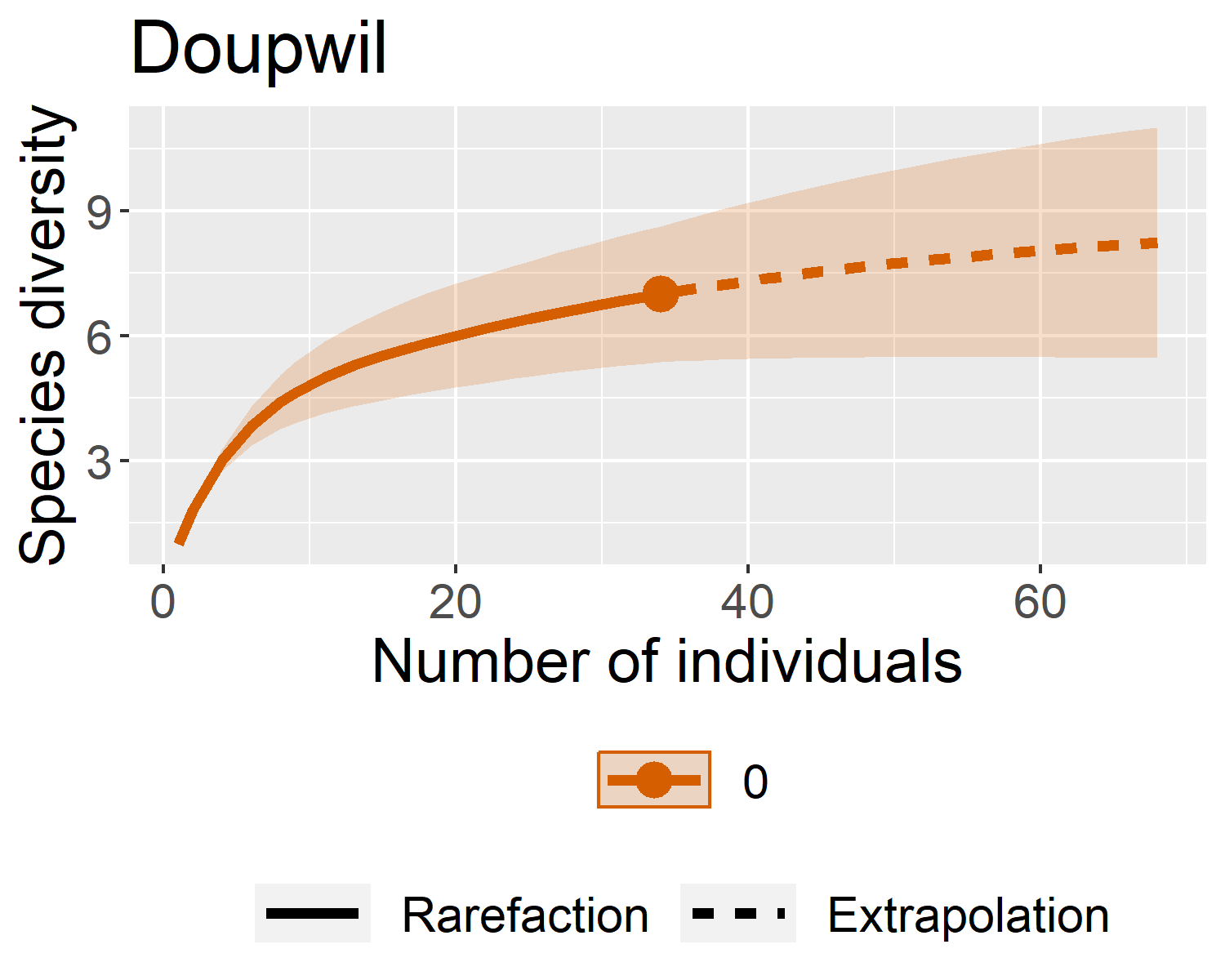
Figure 2.1: location of sites in the analysis

## 2.2 Network construction

## 2.3 Data Quality

## 2.4 quality of data

#> Assemblage m Method Order.q qD qD.LCL qD.UCL  
#> 1 Akumbu12 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 2 Akumbu12 73 Rarefaction 0 4.548649 3.878284 5.219014  
#> 3 Akumbu12 133 Observed 0 5.000000 4.030069 5.969931  
#> 4 Akumbu12 134 Extrapolation 0 5.000000 4.030069 5.969931  
#> 5 Akumbu12 203 Extrapolation 0 5.000000 4.030069 5.969931  
#> 6 Ambere-Dougon 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 7 Ambere-Dougon 18 Rarefaction 0 3.462053 2.545892 4.378214  
#> 8 Ambere-Dougon 33 Observed 0 4.000000 2.940450 5.059550  
#> 9 Ambere-Dougon 34 Extrapolation 0 4.000000 2.930847 5.069153  
#> 10 Ambere-Dougon 50 Extrapolation 0 4.000000 2.804469 5.195531  
#> 11 Damassogou 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 12 Damassogou 99 Rarefaction 0 5.874340 5.222824 6.525857  
#> 13 Damassogou 179 Observed 0 6.000000 5.462877 6.537123  
#> 14 Damassogou 180 Extrapolation 0 6.000000 5.462535 6.537465  
#> 15 Damassogou 273 Extrapolation 0 6.000000 5.384847 6.615153  
#> 16 Doupwil 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 17 Doupwil 18 Rarefaction 0 5.826326 4.456042 7.196609  
#> 18 Doupwil 34 Observed 0 7.000000 4.977437 9.022563  
#> 19 Doupwil 35 Extrapolation 0 7.057093 4.987580 9.126606  
#> 20 Doupwil 52 Extrapolation 0 7.806961 4.999184 10.614738  
#> 21 Essouk 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 22 Essouk 201 Rarefaction 0 7.793897 7.166723 8.421072  
#> 23 Essouk 363 Observed 0 8.000000 7.313013 8.686987  
#> 24 Essouk 364 Extrapolation 0 8.000000 7.312925 8.687075  
#> 25 Essouk 554 Extrapolation 0 8.000000 7.291443 8.708557  
#> 26 Galia 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 27 Galia 72 Rarefaction 0 8.561098 7.587997 9.534198  
#> 28 Galia 130 Observed 0 9.000000 7.995134 10.004866  
#> 29 Galia 131 Extrapolation 0 9.000000 7.992129 10.007871  
#> 30 Galia 198 Extrapolation 0 9.000000 7.768823 10.231177  
#> 31 Gao12 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 32 Gao12 580 Rarefaction 0 6.982758 6.790754 7.174761  
#> 33 Gao12 1045 Observed 0 7.000000 7.000000 7.000000  
#> 34 Gao12 1046 Extrapolation 0 7.000000 7.000000 7.000000  
#> 35 Gao12 1595 Extrapolation 0 7.000000 7.000000 7.000000  
#> 36 Jenne-jeno12 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 37 Jenne-jeno12 98 Rarefaction 0 10.012580 8.776495 11.248665  
#> 38 Jenne-jeno12 178 Observed 0 11.000000 9.338330 12.661670  
#> 39 Jenne-jeno12 179 Extrapolation 0 11.005494 9.337322 12.673666  
#> 40 Jenne-jeno12 272 Extrapolation 0 11.218173 9.038351 13.397995  
#> 41 Kokolo 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 42 Kokolo 66 Rarefaction 0 3.766851 3.009321 4.524382  
#> 43 Kokolo 119 Observed 0 4.000000 3.131564 4.868436  
#> 44 Kokolo 120 Extrapolation 0 4.000000 3.129194 4.870806  
#> 45 Kokolo 182 Extrapolation 0 4.000000 2.981717 5.018283  
#> 46 Mara12 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 47 Mara12 170 Rarefaction 0 6.807439 6.171694 7.443185  
#> 48 Mara12 307 Observed 0 7.000000 6.462877 7.537123  
#> 49 Mara12 308 Extrapolation 0 7.000000 6.462645 7.537355  
#> 50 Mara12 469 Extrapolation 0 7.000000 6.393386 7.606614  
#> 51 Ounjougou12 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 52 Ounjougou12 12 Rarefaction 0 3.043142 2.459375 3.626909  
#> 53 Ounjougou12 23 Observed 0 4.000000 3.208055 4.791945  
#> 54 Ounjougou12 24 Extrapolation 0 4.079710 3.263728 4.895692  
#> 55 Ounjougou12 35 Extrapolation 0 4.619830 3.625541 5.614120  
#> 56 Sadia12 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 57 Sadia12 1853 Rarefaction 0 5.000000 5.000000 5.000000  
#> 58 Sadia12 3336 Observed 0 5.000000 5.000000 5.000000  
#> 59 Sadia12 3337 Extrapolation 0 5.000000 5.000000 5.000000  
#> 60 Sadia12 5092 Extrapolation 0 5.000000 5.000000 5.000000  
#> 61 Sanga D 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 62 Sanga D 52 Rarefaction 0 9.074661 7.620311 10.529010  
#> 63 Sanga D 95 Observed 0 10.000000 8.152883 11.847117  
#> 64 Sanga D 96 Extrapolation 0 10.010307 8.151064 11.869550  
#> 65 Sanga D 145 Extrapolation 0 10.322071 7.901572 12.742571  
#> 66 Shoma12 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 67 Shoma12 323 Rarefaction 0 6.108062 5.406964 6.809160  
#> 68 Shoma12 583 Observed 0 7.000000 6.142466 7.857534  
#> 69 Shoma12 584 Extrapolation 0 7.003419 6.145885 7.860953  
#> 70 Shoma12 890 Extrapolation 0 7.650054 6.792520 8.507589  
#> 71 TMD12 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 72 TMD12 104 Rarefaction 0 10.387753 9.476064 11.299442  
#> 73 TMD12 188 Observed 0 11.000000 9.945642 12.054358  
#> 74 TMD12 189 Extrapolation 0 11.000000 9.943571 12.056429  
#> 75 TMD12 287 Extrapolation 0 11.000000 9.739401 12.260599  
#> 76 Togu 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 77 Togu 69 Rarefaction 0 6.874672 5.567955 8.181390  
#> 78 Togu 126 Observed 0 8.000000 6.272180 9.727820  
#> 79 Togu 127 Extrapolation 0 8.015623 6.279516 9.751730  
#> 80 Togu 192 Extrapolation 0 8.644083 6.384244 10.903923  
#> SC SC.LCL SC.UCL  
#> 1 0.2871953 0.2581355 0.3162551  
#> 2 0.9924440 0.9855425 0.9993455  
#> 3 1.0000000 1.0000000 1.0000000  
#> 4 1.0000000 1.0000000 1.0000000  
#> 5 1.0000000 1.0000000 1.0000000  
#> 6 0.3996212 0.2643006 0.5349419  
#> 7 0.9530129 0.9217661 0.9842597  
#> 8 1.0000000 0.9723371 1.0000000  
#> 9 1.0000000 0.9739643 1.0000000  
#> 10 1.0000000 0.9901303 1.0000000  
#> 11 0.3331869 0.2911970 0.3751767  
#> 12 0.9948088 0.9894217 1.0000000  
#> 13 1.0000000 0.9954902 1.0000000  
#> 14 1.0000000 0.9955403 1.0000000  
#> 15 1.0000000 0.9984223 1.0000000  
#> 16 0.1871658 0.1163388 0.2579928  
#> 17 0.9082100 0.8474235 0.9689965  
#> 18 0.9429066 0.8773096 1.0000000  
#> 19 0.9445858 0.8803857 1.0000000  
#> 20 0.9666407 0.9207690 1.0000000  
#> 21 0.3530889 0.3111504 0.3950274  
#> 22 0.9972636 0.9948459 0.9996813  
#> 23 1.0000000 0.9989371 1.0000000  
#> 24 1.0000000 0.9989429 1.0000000  
#> 25 1.0000000 0.9996289 1.0000000  
#> 26 0.2019082 0.1608447 0.2429717  
#> 27 0.9830500 0.9726824 0.9934176  
#> 28 1.0000000 0.9886586 1.0000000  
#> 29 1.0000000 0.9888123 1.0000000  
#> 30 1.0000000 0.9949423 1.0000000  
#> 31 0.2909971 0.2785809 0.3034133  
#> 32 0.9998145 0.9992496 1.0000000  
#> 33 1.0000000 1.0000000 1.0000000  
#> 34 1.0000000 1.0000000 1.0000000  
#> 35 1.0000000 1.0000000 1.0000000  
#> 36 0.2595696 0.2186892 0.3004500  
#> 37 0.9783703 0.9677330 0.9890075  
#> 38 0.9945062 0.9833796 1.0000000  
#> 39 0.9946276 0.9835756 1.0000000  
#> 40 0.9993277 0.9926736 1.0000000  
#> 41 0.7048853 0.6105979 0.7991728  
#> 42 0.9898095 0.9808362 0.9987827  
#> 43 1.0000000 0.9910034 1.0000000  
#> 44 1.0000000 0.9911533 1.0000000  
#> 45 1.0000000 0.9968795 1.0000000  
#> 46 0.2438313 0.2268166 0.2608460  
#> 47 0.9955354 0.9920787 0.9989921  
#> 48 1.0000000 0.9975571 1.0000000  
#> 49 1.0000000 0.9975748 1.0000000  
#> 50 1.0000000 0.9991929 1.0000000  
#> 51 0.4189723 0.2911919 0.5467528  
#> 52 0.9127987 0.8716695 0.9539280  
#> 53 0.9202899 0.8862954 0.9542843  
#> 54 0.9269324 0.8957708 0.9580939  
#> 55 0.9719424 0.9599765 0.9839083  
#> 56 0.3861407 0.3760217 0.3962598  
#> 57 1.0000000 1.0000000 1.0000000  
#> 58 1.0000000 1.0000000 1.0000000  
#> 59 1.0000000 1.0000000 1.0000000  
#> 60 1.0000000 1.0000000 1.0000000  
#> 61 0.1742441 0.1397021 0.2087862  
#> 62 0.9609123 0.9395615 0.9822630  
#> 63 0.9896930 0.9681701 1.0000000  
#> 64 0.9899077 0.9685992 1.0000000  
#> 65 0.9964028 0.9823191 1.0000000  
#> 66 0.4166622 0.3836215 0.4497030  
#> 67 0.9965695 0.9951882 0.9979508  
#> 68 0.9965812 0.9965812 0.9965812  
#> 69 0.9965929 0.9965929 0.9965929  
#> 70 0.9988074 0.9988074 0.9988074  
#> 71 0.1959836 0.1667412 0.2252260  
#> 72 0.9877691 0.9804762 0.9950621  
#> 73 1.0000000 0.9924419 1.0000000  
#> 74 1.0000000 0.9925234 1.0000000  
#> 75 1.0000000 0.9971010 1.0000000  
#> 76 0.3799365 0.3349282 0.4249449  
#> 77 0.9717105 0.9559513 0.9874696  
#> 78 0.9843770 0.9686523 1.0000000  
#> 79 0.9846230 0.9690119 1.0000000  
#> 80 0.9945200 0.9840493 1.0000000



#> Assemblage m Method Order.q qD qD.LCL qD.UCL  
#> 1 Akumbu9 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 2 Akumbu9 154 Rarefaction 0 3.985292 3.831399 4.139185  
#> 3 Akumbu9 278 Observed 0 4.000000 4.000000 4.000000  
#> 4 Akumbu9 279 Extrapolation 0 4.000000 4.000000 4.000000  
#> 5 Akumbu9 424 Extrapolation 0 4.000000 4.000000 4.000000  
#> 6 Gao9 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 7 Gao9 208 Rarefaction 0 6.996687 6.932780 7.060594  
#> 8 Gao9 376 Observed 0 7.000000 7.000000 7.000000  
#> 9 Gao9 377 Extrapolation 0 7.000000 7.000000 7.000000  
#> 10 Gao9 574 Extrapolation 0 7.000000 7.000000 7.000000  
#> 11 Jenne-jeno9 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 12 Jenne-jeno9 297 Rarefaction 0 9.564521 6.667326 12.461715  
#> 13 Jenne-jeno9 536 Observed 0 12.000000 7.467887 16.532113  
#> 14 Jenne-jeno9 537 Extrapolation 0 12.009321 7.470865 16.547778  
#> 15 Jenne-jeno9 818 Extrapolation 0 14.370987 8.046345 20.695628  
#> 16 Mara9 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 17 Mara9 129 Rarefaction 0 10.452859 8.867533 12.038184  
#> 18 Mara9 234 Observed 0 12.000000 9.519239 14.480761  
#> 19 Mara9 235 Extrapolation 0 12.012784 9.523448 14.502120  
#> 20 Mara9 357 Extrapolation 0 13.327733 9.780401 16.875064  
#> 21 Marakaduguba 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 22 Marakaduguba 20 Rarefaction 0 5.030420 3.644613 6.416227  
#> 23 Marakaduguba 37 Observed 0 6.000000 4.291802 7.708198  
#> 24 Marakaduguba 38 Extrapolation 0 6.024324 4.295738 7.752911  
#> 25 Marakaduguba 56 Extrapolation 0 6.210385 4.116084 8.304685  
#> 26 Nin\_Bere 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 27 Nin\_Bere 14 Rarefaction 0 1.966890 1.777762 2.156018  
#> 28 Nin\_Bere 26 Observed 0 2.000000 2.000000 2.000000  
#> 29 Nin\_Bere 27 Extrapolation 0 2.000000 2.000000 2.000000  
#> 30 Nin\_Bere 40 Extrapolation 0 2.000000 2.000000 2.000000  
#> 31 Sadia9 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 32 Sadia9 358 Rarefaction 0 4.999998 4.998939 5.001058  
#> 33 Sadia9 645 Observed 0 5.000000 5.000000 5.000000  
#> 34 Sadia9 646 Extrapolation 0 5.000000 5.000000 5.000000  
#> 35 Sadia9 984 Extrapolation 0 5.000000 5.000000 5.000000  
#> 36 TMD9 1 Rarefaction 0 1.000000 1.000000 1.000000  
#> 37 TMD9 51 Rarefaction 0 9.275916 8.108082 10.443750  
#> 38 TMD9 92 Observed 0 10.000000 8.415615 11.584385  
#> 39 TMD9 93 Extrapolation 0 10.010636 8.415511 11.605761  
#> 40 TMD9 140 Extrapolation 0 10.320373 8.224534 12.416211  
#> SC SC.LCL SC.UCL  
#> 1 0.7061787 0.6432925 0.7690650  
#> 2 0.9992883 0.9971360 1.0000000  
#> 3 1.0000000 1.0000000 1.0000000  
#> 4 1.0000000 1.0000000 1.0000000  
#> 5 1.0000000 1.0000000 1.0000000  
#> 6 0.2202128 0.1978120 0.2426136  
#> 7 0.9998620 0.9989395 1.0000000  
#> 8 1.0000000 1.0000000 1.0000000  
#> 9 1.0000000 1.0000000 1.0000000  
#> 10 1.0000000 1.0000000 1.0000000  
#> 11 0.2394546 0.2273769 0.2515323  
#> 12 0.9888186 0.9806782 0.9969589  
#> 13 0.9906786 0.9834308 0.9979264  
#> 14 0.9906856 0.9834373 0.9979339  
#> 15 0.9924500 0.9853799 0.9995200  
#> 16 0.1756355 0.1495963 0.2016747  
#> 17 0.9833016 0.9725625 0.9940406  
#> 18 0.9872161 0.9763522 0.9980799  
#> 19 0.9872525 0.9763933 0.9981118  
#> 20 0.9910042 0.9814133 1.0000000  
#> 21 0.4369369 0.2375784 0.6362955  
#> 22 0.9053056 0.8644820 0.9461293  
#> 23 0.9756757 0.9266229 1.0000000  
#> 24 0.9781081 0.9304270 1.0000000  
#> 25 0.9967141 0.9659857 1.0000000  
#> 26 0.7292308 0.5561602 0.9023014  
#> 27 0.9889632 0.9682751 1.0000000  
#> 28 1.0000000 1.0000000 1.0000000  
#> 29 1.0000000 1.0000000 1.0000000  
#> 30 1.0000000 1.0000000 1.0000000  
#> 31 0.3593047 0.3328363 0.3857732  
#> 32 0.9999999 0.9999730 1.0000000  
#> 33 1.0000000 1.0000000 1.0000000  
#> 34 1.0000000 1.0000000 1.0000000  
#> 35 1.0000000 1.0000000 1.0000000  
#> 36 0.1734353 0.1369264 0.2099441  
#> 37 0.9709037 0.9499110 0.9918964  
#> 38 0.9893642 0.9689782 1.0000000  
#> 39 0.9895929 0.9694601 1.0000000  
#> 40 0.9962539 0.9837353 1.0000000

# 3 Analysis

## 3.1 Multiplex structure

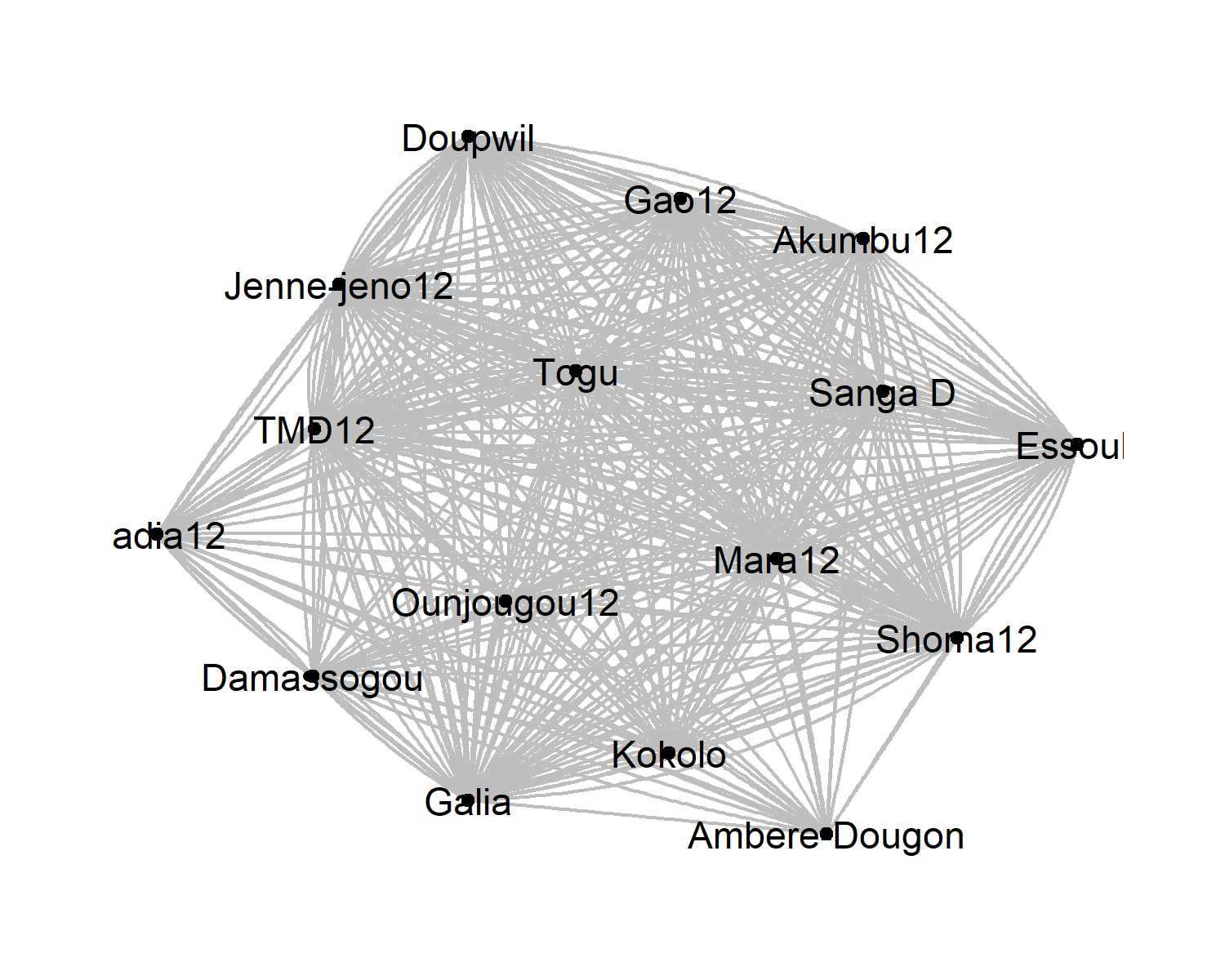


Figure 3.1: Plot of 11th century AD network of decorative practices. The plot shows the very strongly connected structure of the network.

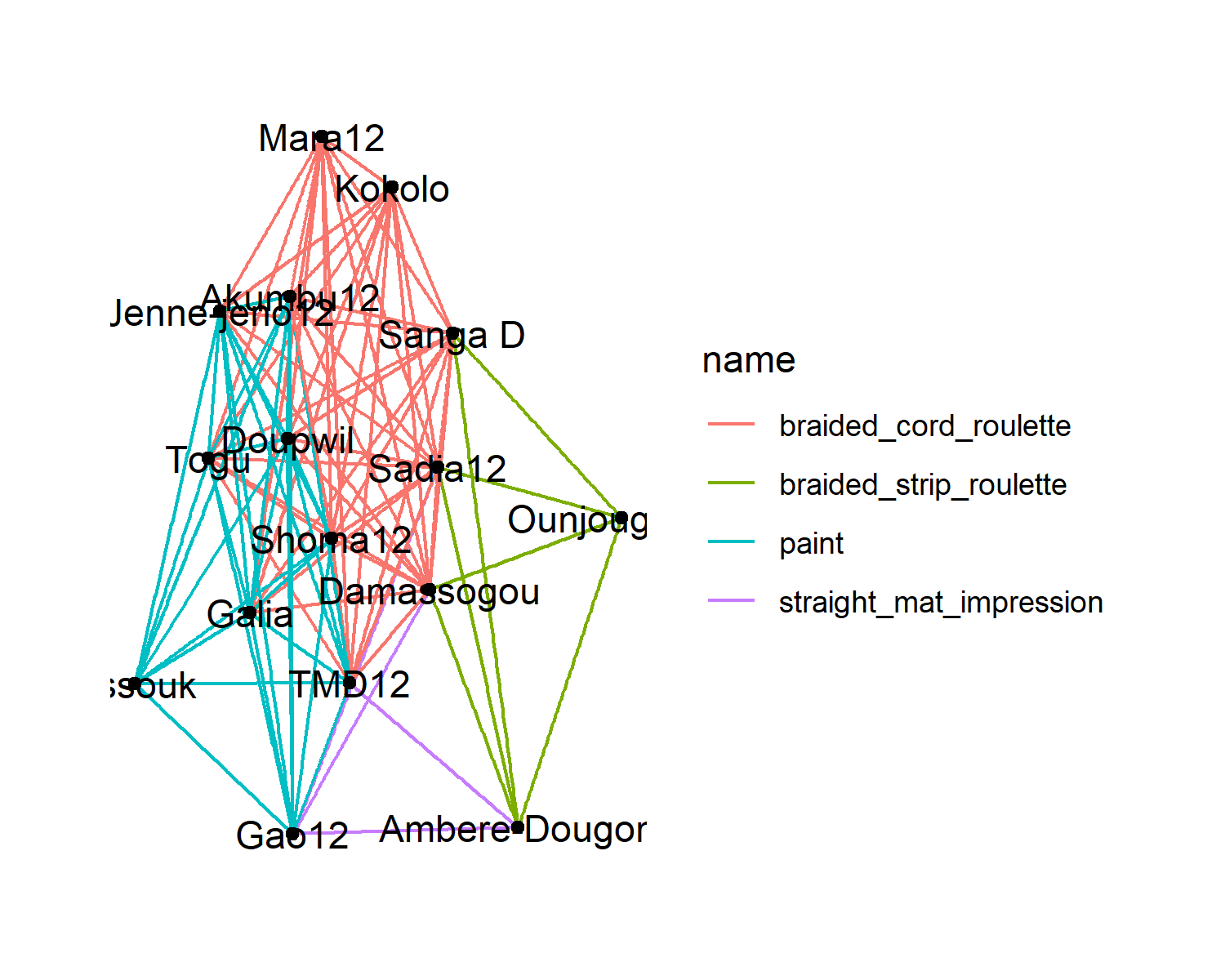


Figure 3.2: Partially overlapping networks of four decorative practices

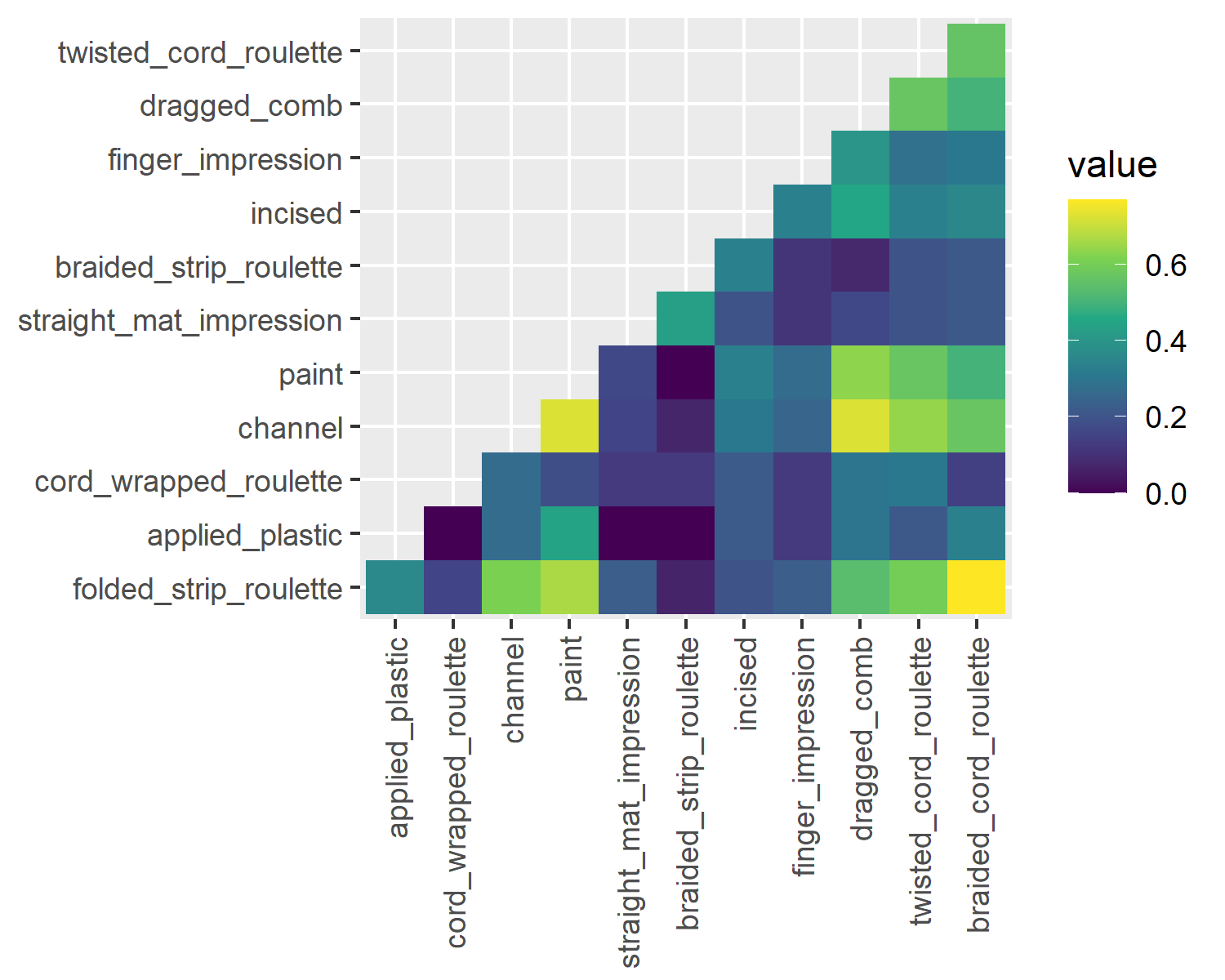


Figure 3.3: Jaccard similarity of nodes present in the networks of individual decorative practices

## 3.2 Sparsification

### 3.2.1 Simplified network backbone

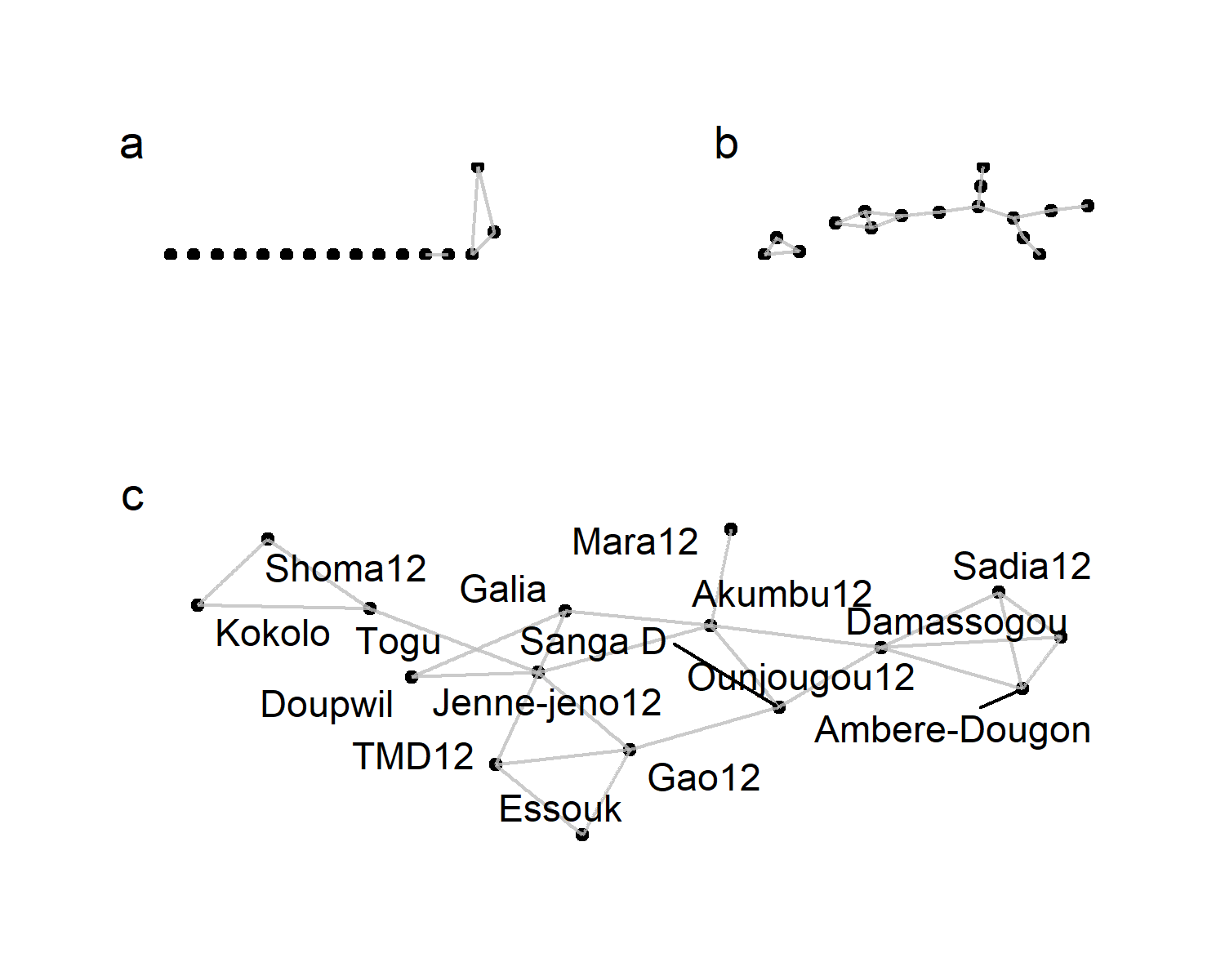
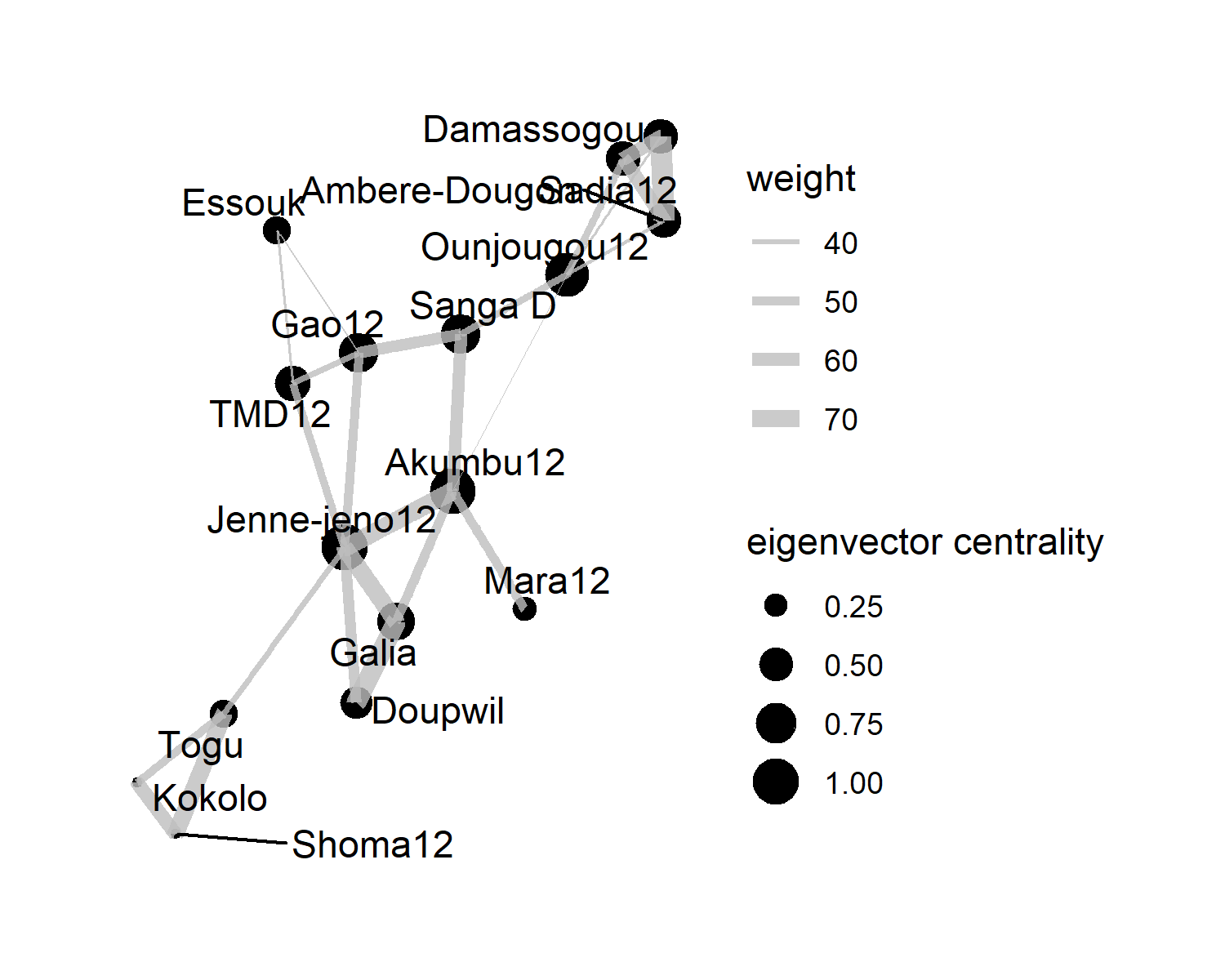


Figure 3.4: Extraction of binary backbones at decreasing significance levels: a) 0.05, b) 0.15, c) 0.18



### 3.2.2 Influential nodes

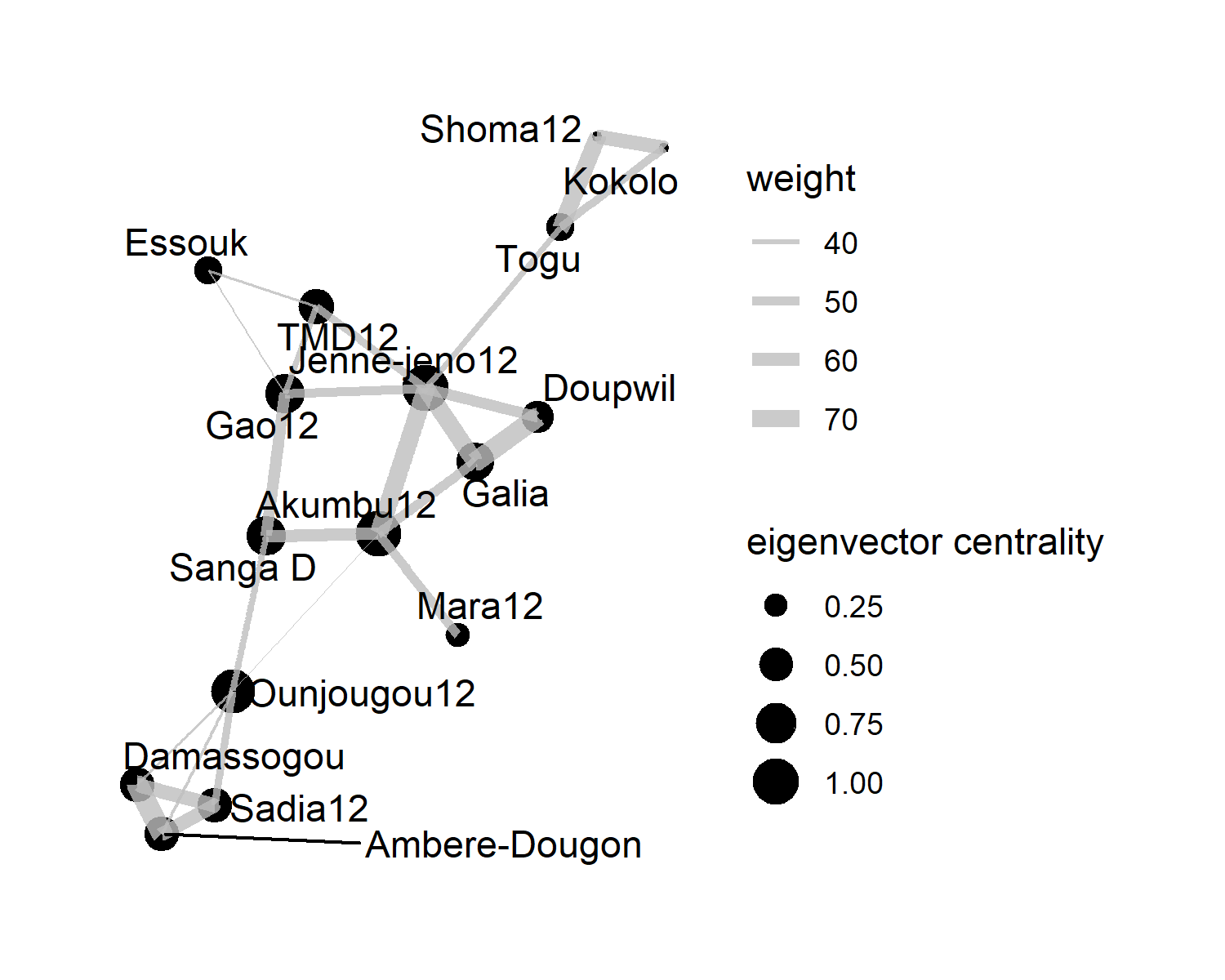


Figure 3.5: Binary backbone at alpha = 0.15 showing eigenvector centralities

### 3.2.3 Brokers

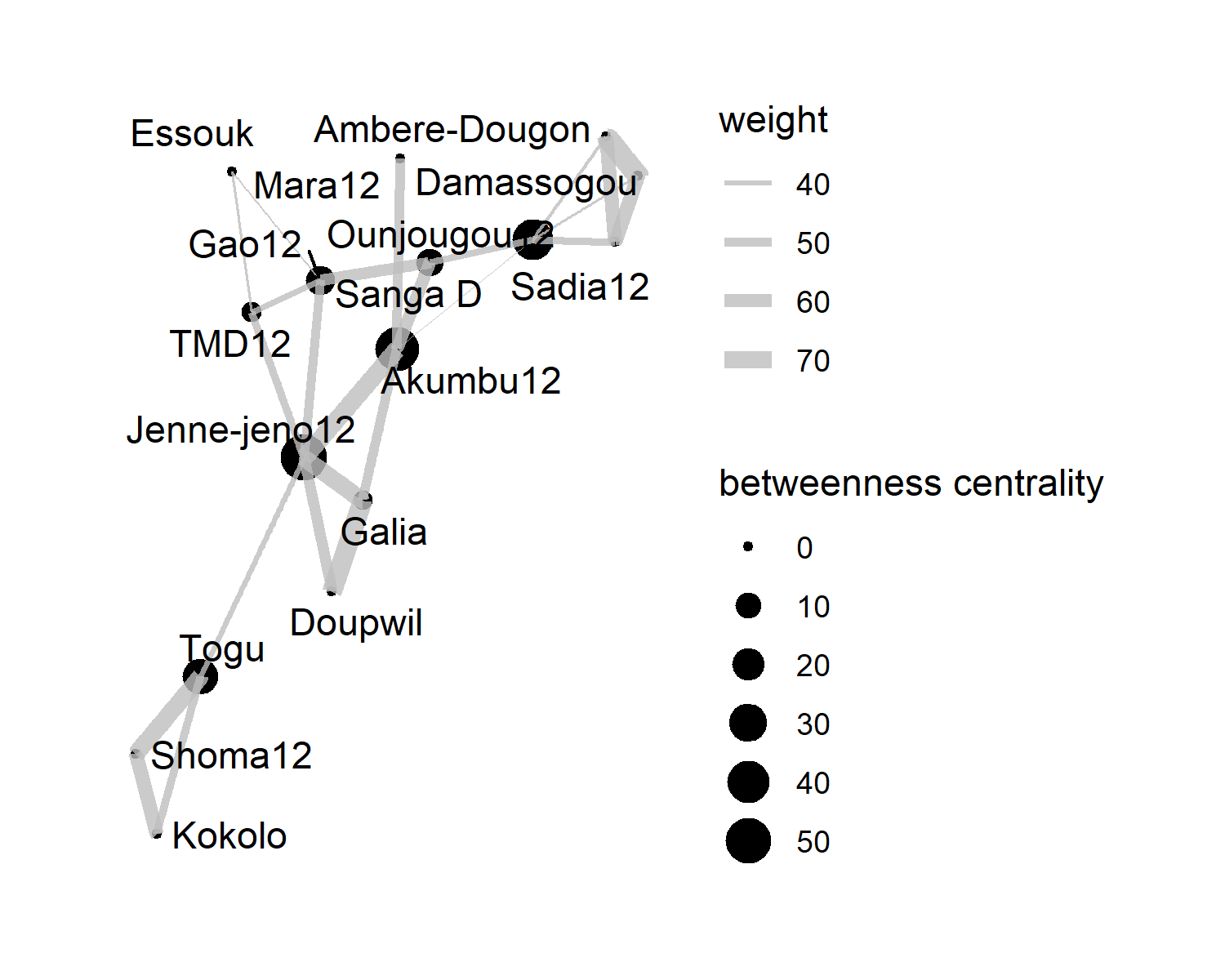


Figure 3.6: Binary backbone at alpha = 0.15 showing betweenness centralities

### 3.2.4 Evaluating measurements

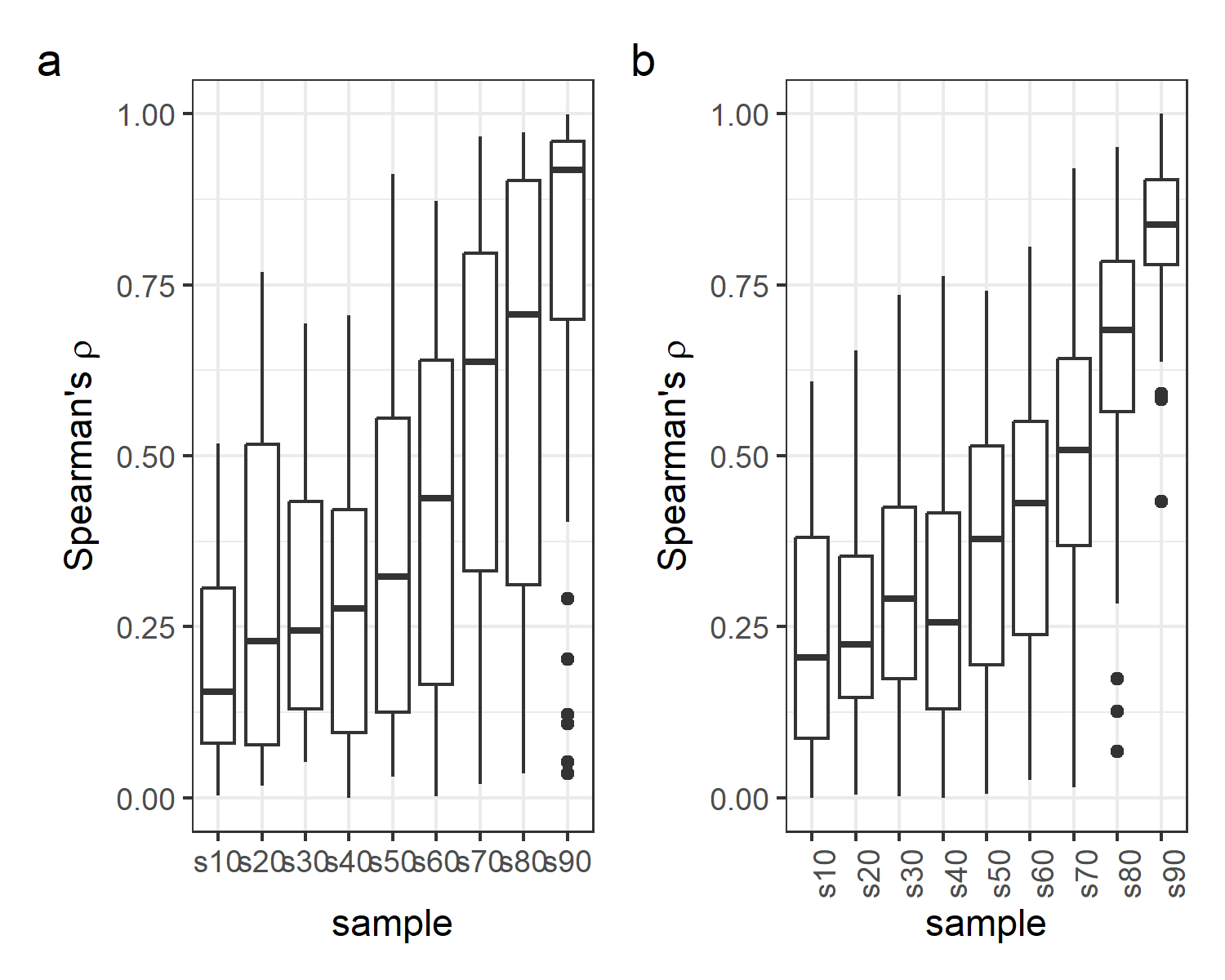


Figure 3.7: Testing the robustness of the bb-network by comparing its centralities to the original graph

## 3.3 Community detection

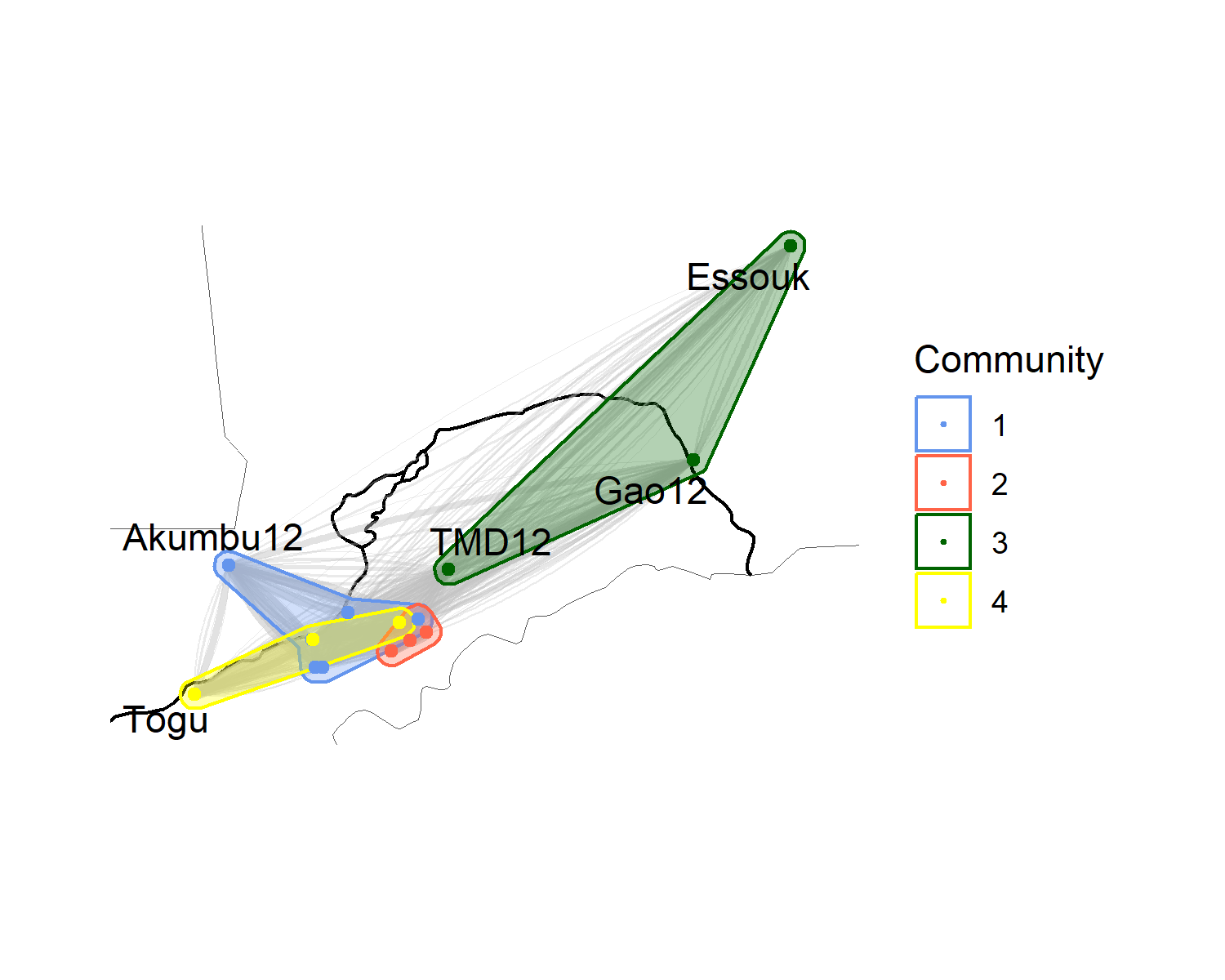
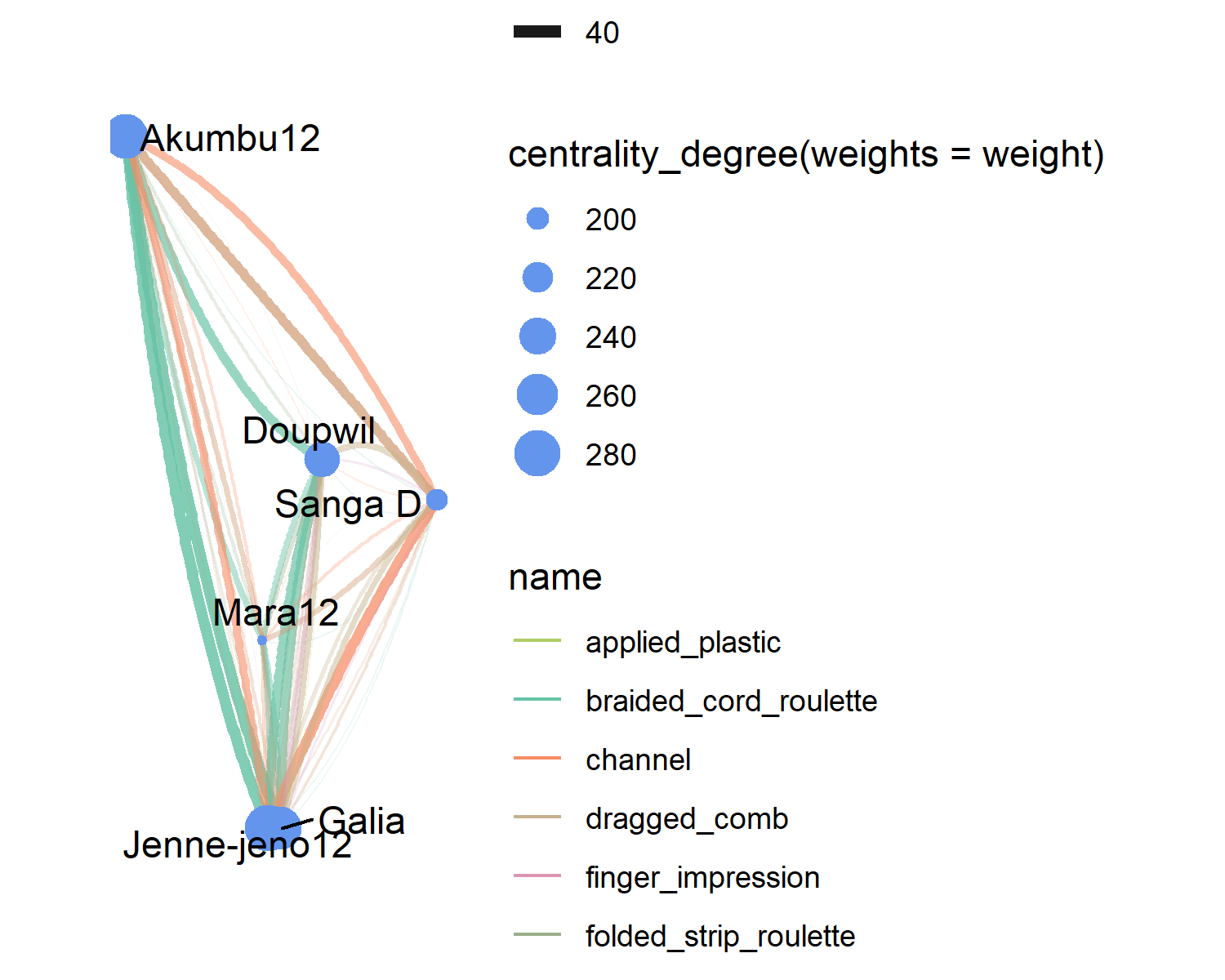
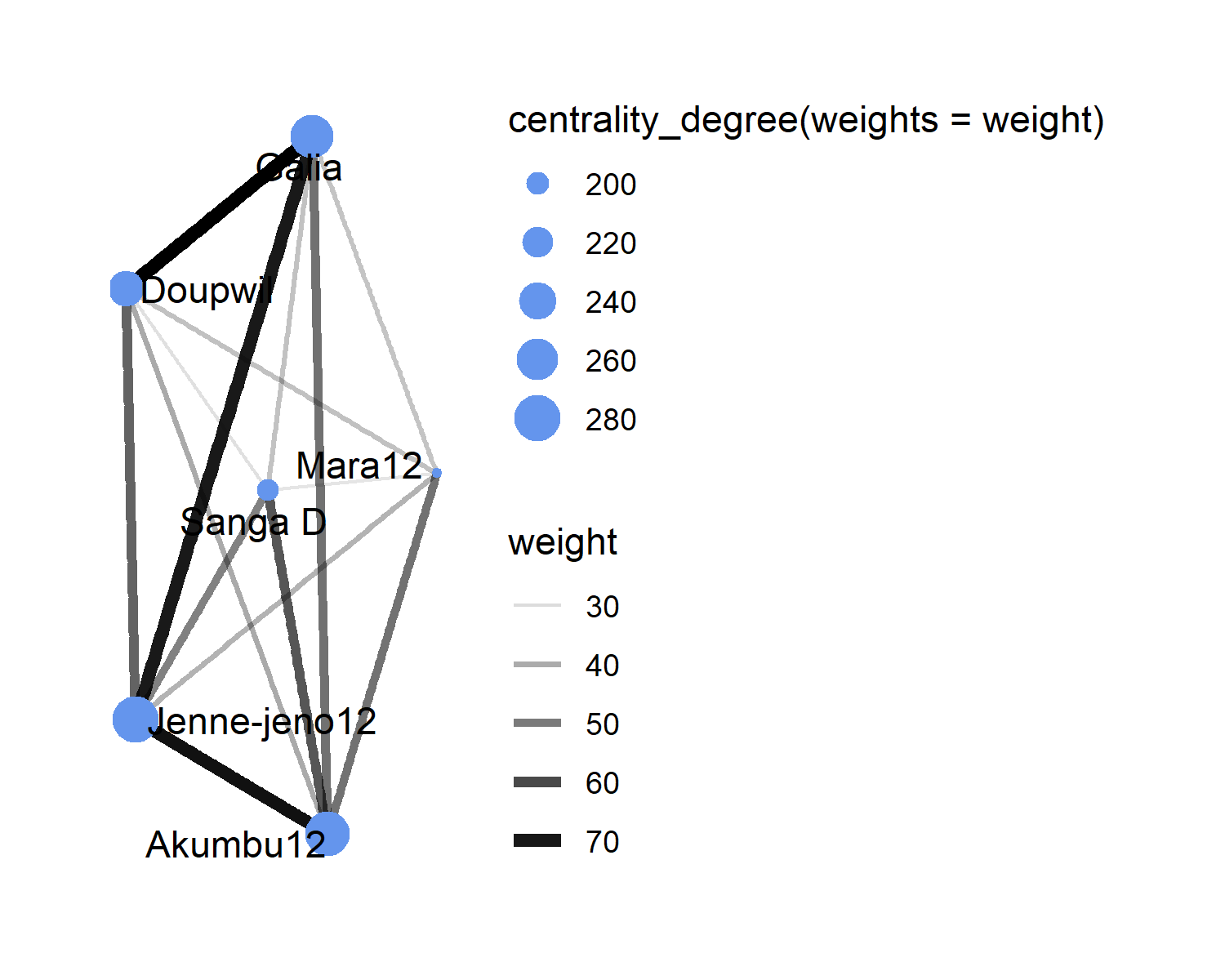
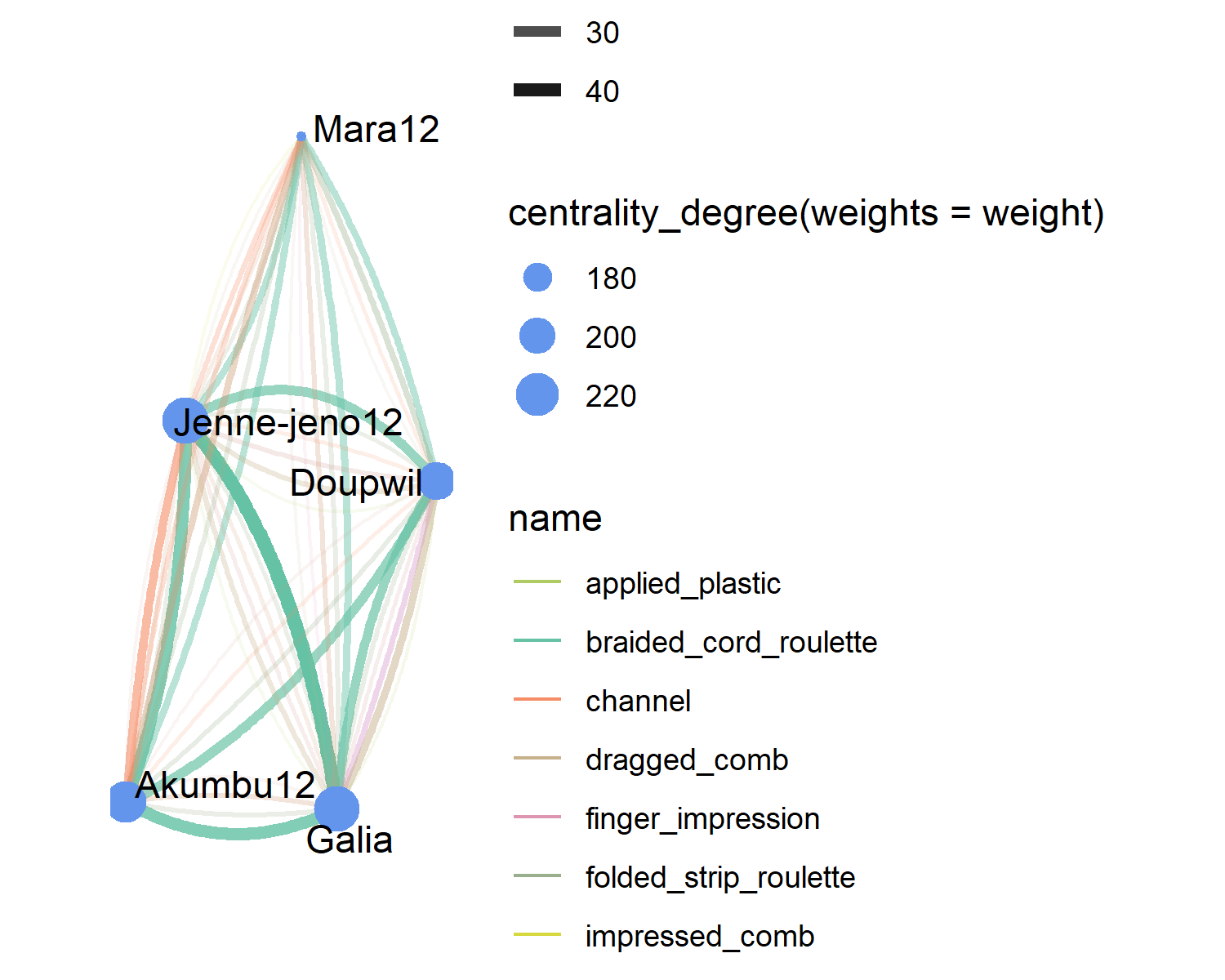


Figure 3.8: Louvain communities within the decor network



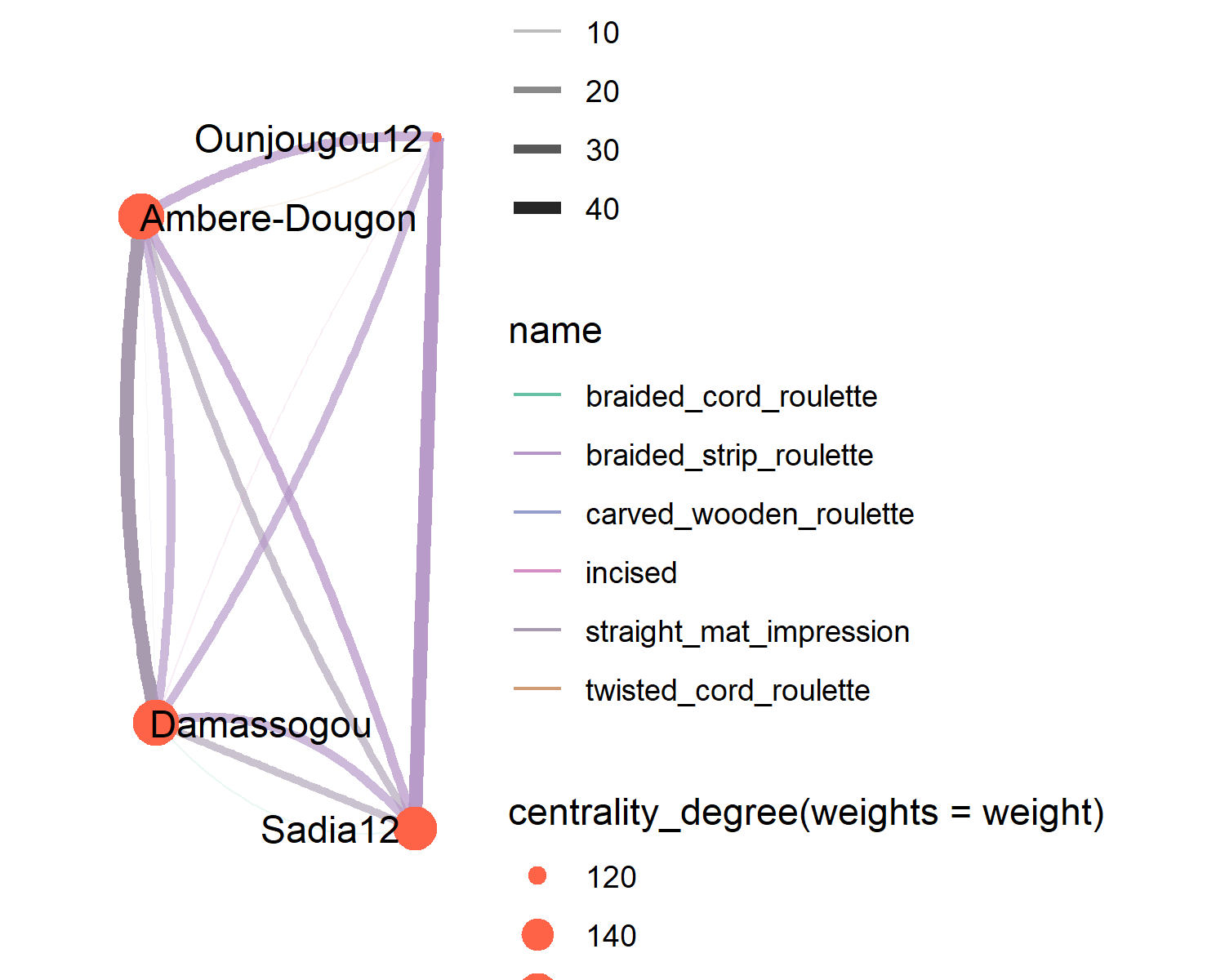


Figure 3.12: Internal connections within community 2

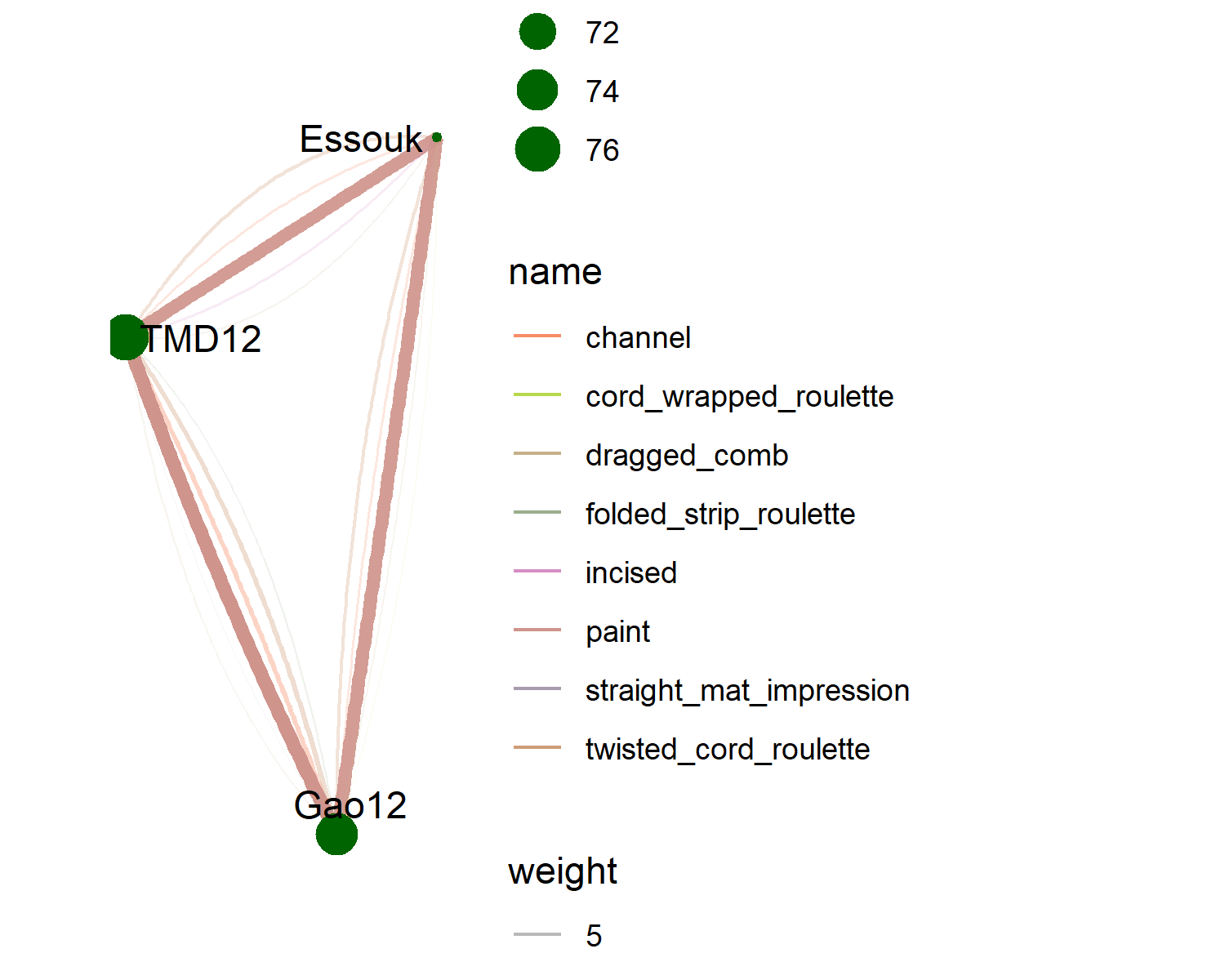


Figure 3.13: Internal connections within community 3

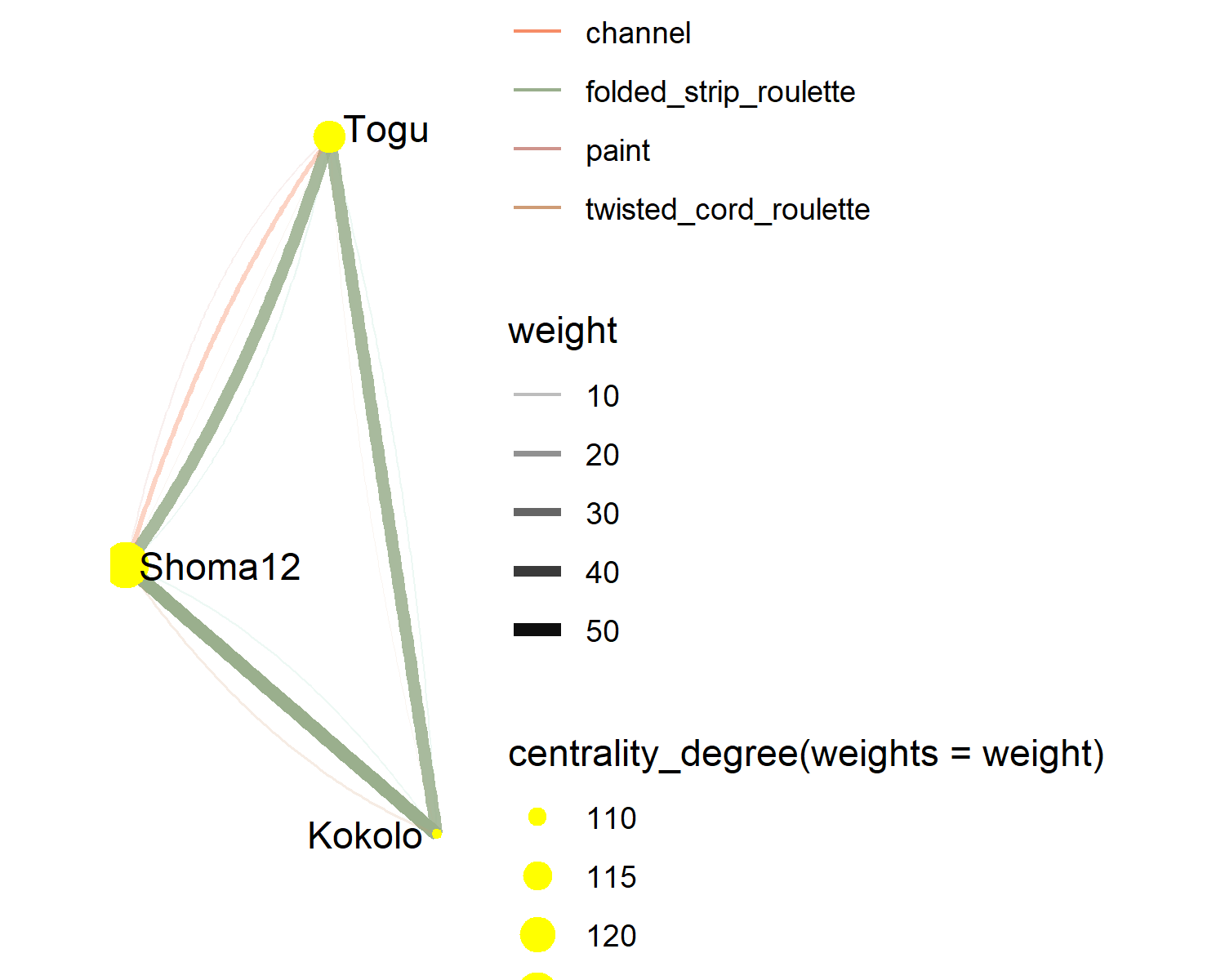


Figure 3.14: Internal connections within community 3

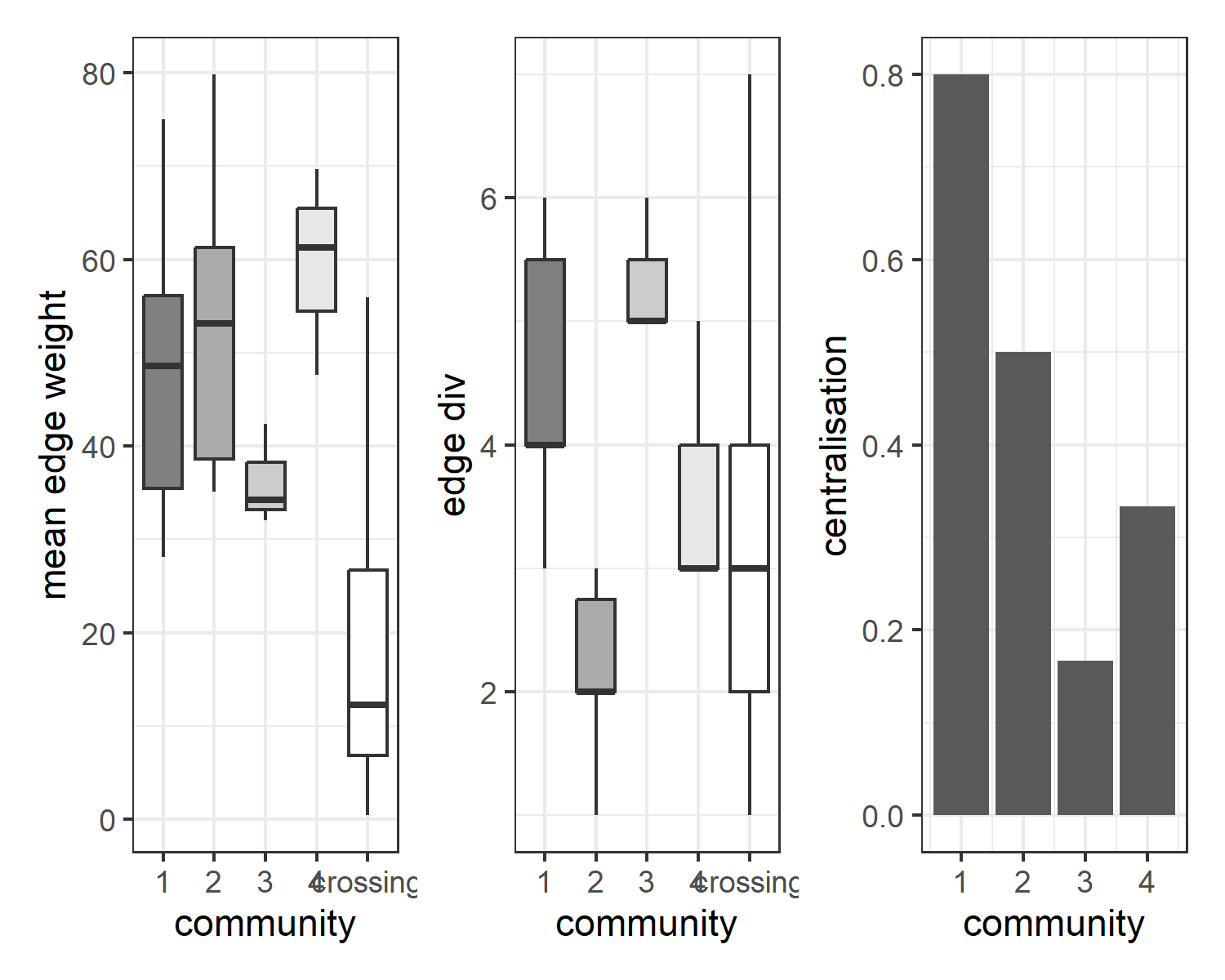
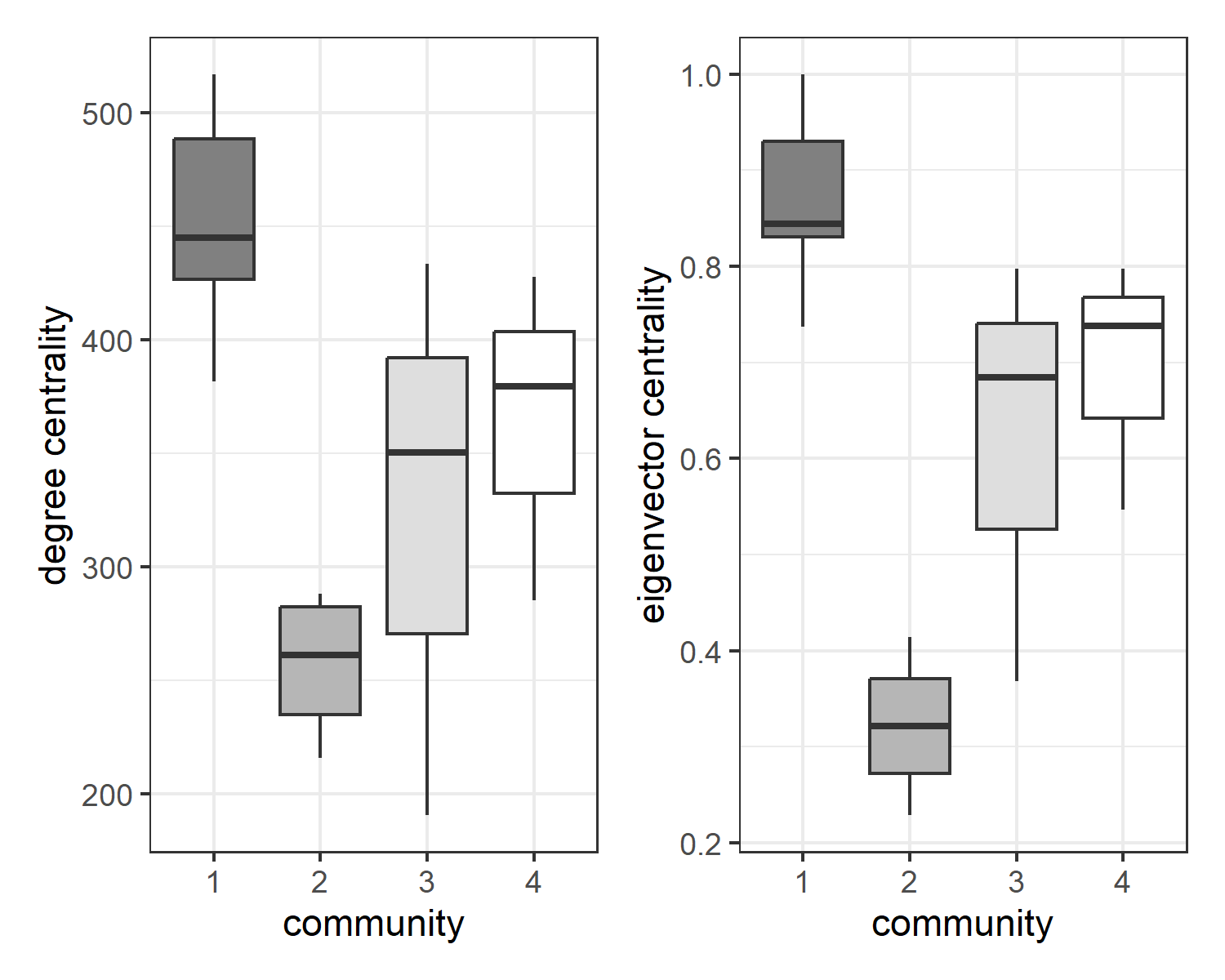


Figure 3.15: Relative edge weights, edge diversity and centralization by cluster



(#fig:cluster\_centralities)Distribution of weighted degree and eigenvector centralities by community.

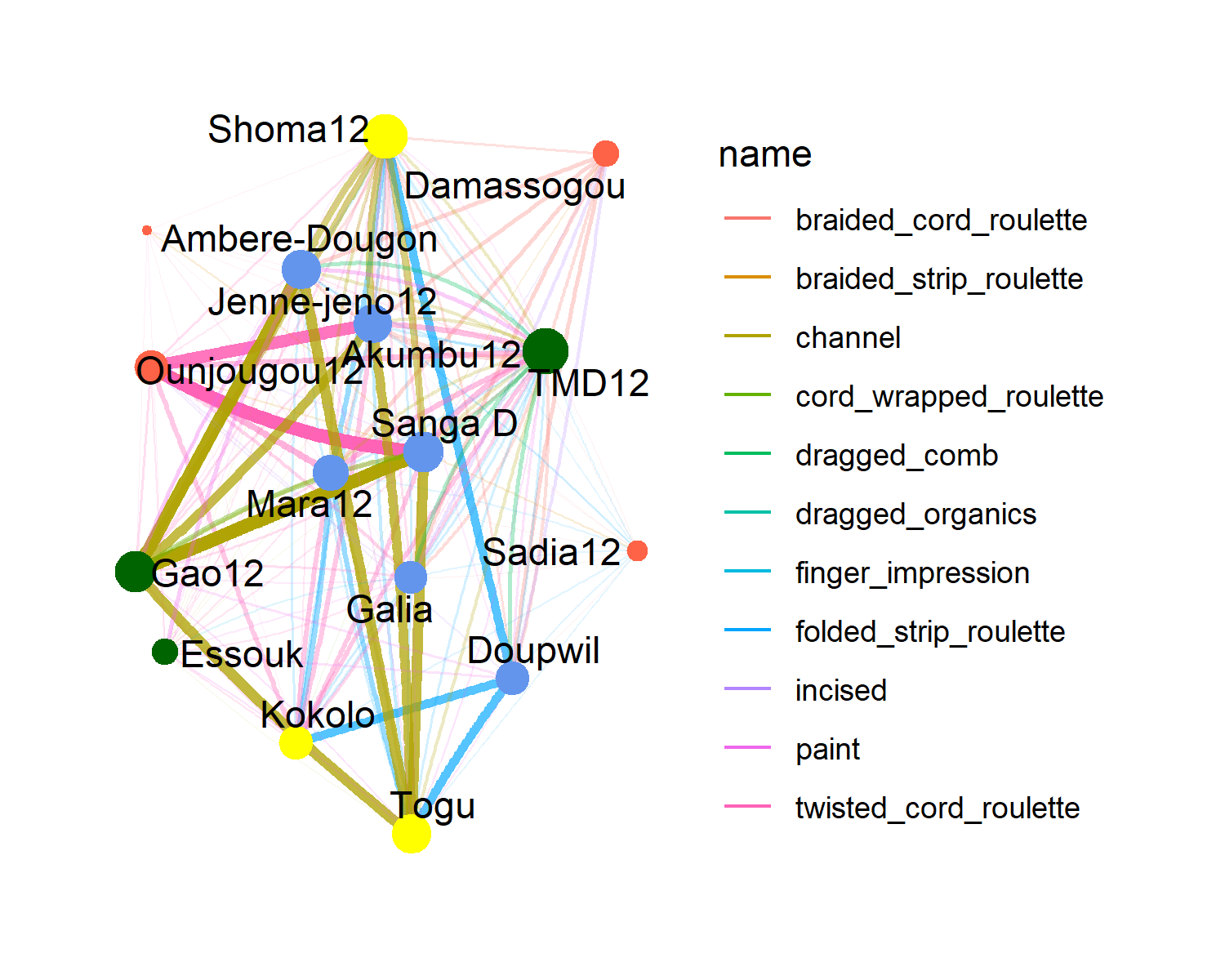


Figure 3.16: Network of edges which cross between clusters

## 3.4 Diachronic analysis

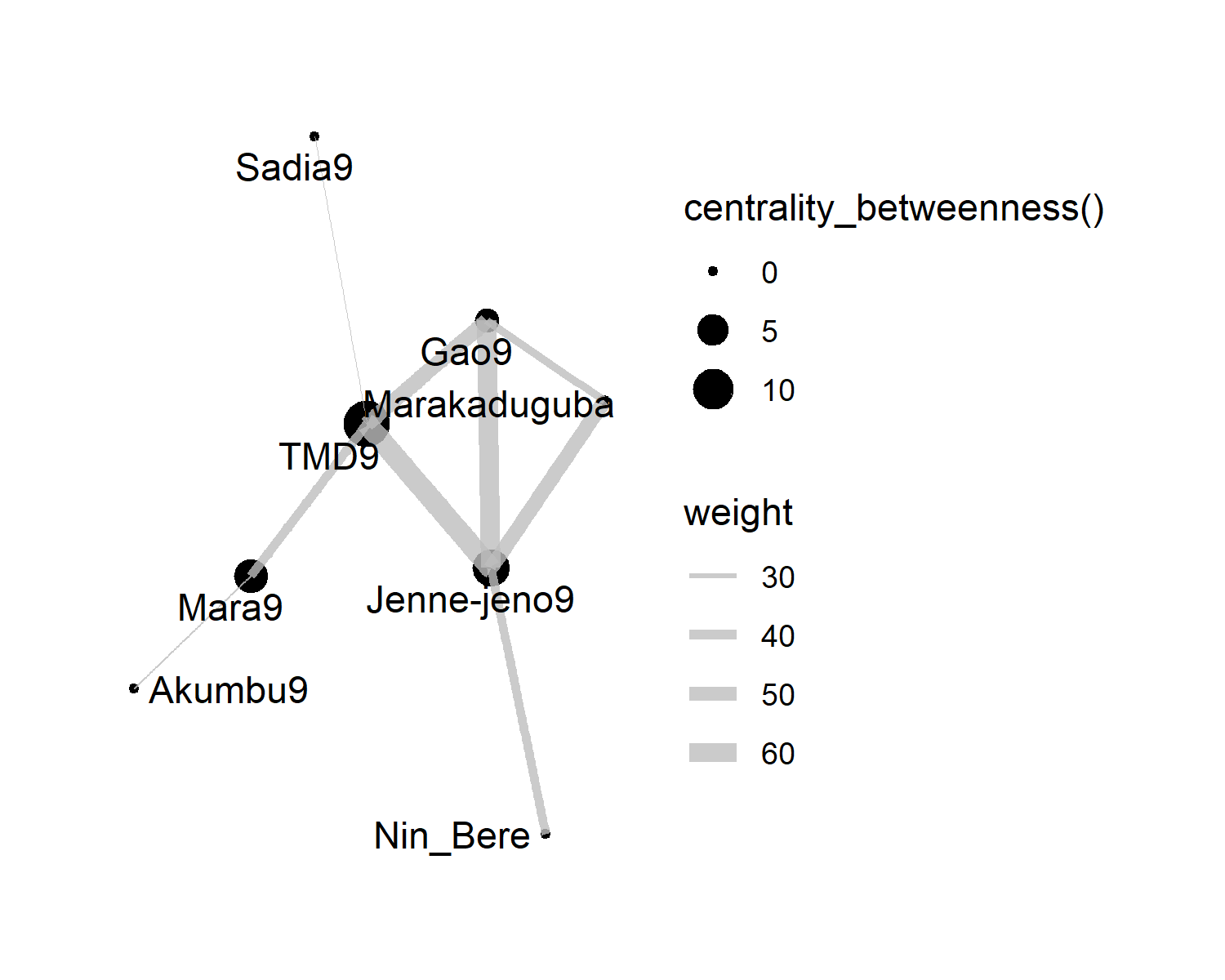


Figure 3.17: early backbone

# 4 Discussion

# 5 Conclusion

# 6 Acknowledgements

The work presented here was undertaken as part of the project “Borrowed words and shared objects” within the German Research Foundation’s (DFG) Priority Programme “Entangled Africa”. Nikolas Gestrich was responsible for the research design and implementation. He is the main author of the analysis code and the manuscript. Juan-Marco Puerta Schardt aided in collating the data and co-authored the analysis code, particularly the section on community detection. He also contributed to the draft versions of the manuscript. The authors wish to thank the Institut des Sciences Humaines du Mali, the Musée National du Mali, and the Rijksmuseum voor Volkenkunde in Leiden for access to their pottery collections, and Susan McIntosh and Douglas Post Park for providing primary data. The R compendium for this article was created using the rrtools package.

### 6.0.1 Colophon

This report was generated on 2024-06-10 12:38:14.269886 using the following computational environment and dependencies:

The current Git commit details are:

#> Local: master D:/Git/pottery\_decor\_as\_networks  
#> Remote: master @ origin (https://github.com/AHWA-Lab-Frankfurt/pottery\_decor\_as\_networks.git)  
#> Head: [4b0408c] 2024-06-03: adaption