SOLIDAGO FLOWER ARTHROPOD NETWORK MODELING AND ANALYSES

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Contents

Network Modelling Summary.

(1) Species with abundances of two or less were removed (see above)
(2) The data were separated into two graphs, **Elk** and **No Elk** exposure
(3) The p-values for the correlation tests were not corrected for experimentwise error

Meta-Data.

- Solidago Pollinator Network Analyses
- Project Director: Dave Smith
- Data Recorder: Ryan ? (undergrad assistant)
- NOTE FROM DAVE ABOUT PREVIOUS ANALYSES: I did not include population FS in my analysis for elk / no-elk. Although, they could be useful data for looking at heritability or perhaps something else. Also, for my analysis, I only included families with more than one rep (I also did an analysis including only families with 3 or more reps). And, I removed singletons from the data.

1. Analyses and Figures

1.1. Package Dependencies.

```
NULL
> require(ecodist)
> require(sna)
> require(vegan)
> require(xtable)
> source("/Users/Aeolus/Documents/Active_Projects/CorNets/CorNets.R")
> bin.sum = function(x) {
+     x[x != 0] = 1
+     sum(x)
+ }
```

1.2. Data Summary.

```
> data = read.csv("SolidagoPollinators2010.csv")
> summary(data)
```

```
      Family      Individual   RandomNmbr          Population  Elk.
 FS 16   : 14   A      :38   Min.   :0.0001008   FS     :51      :51
 Kiwi 10 : 13   B      :30   1st Qu.:0.2579153   Ft Vall:26   No :65
 FS 18   : 11   C      :25   Median :0.5235663   Grnhs  :21   Yes:96
 Grnhs 10:  9   D      :21   Mean   :0.5124183   K In   :30
 Kiwi 28 :  9   E      :16   3rd Qu.:0.7546771   K Out  :31
 FS 22   :  8   F      :14   Max.   :0.9986857   Keeli  :39
 (Other) :148   (Other):68                      Thorpe :14
               Notes       Florettes      Flors.per.stalk   Date.of.Flwr
                  :208   Min.   :  7.00   Min.   :  2.25   Min.   :  1.00
 only 1 srvy date?:  1   1st Qu.: 37.00   1st Qu.: 18.65   1st Qu.: 67.00
 only 1 survey    :  1   Median : 65.50   Median : 32.67   Median : 77.00
 only 2 survey    :  1   Mean   : 78.05   Mean   : 46.51   Mean   : 77.57
 Only one sample? :  1   3rd Qu.: 96.25   3rd Qu.: 66.62   3rd Qu.: 91.00
                         Max.   :281.00   Max.   :227.00   Max.   :113.00

 Date.of.Srvy    Total.Height.mm.     Stalks          Ramets
 Min.   : 65.00   Min.   :107.0    Min.   :1.000   Min.   :0.0000
 1st Qu.: 66.25   1st Qu.:290.2    1st Qu.:1.000   1st Qu.:0.0000
 Median : 67.50   Median :342.0    Median :2.000   Median :0.0000
 Mean   : 67.50   Mean   :344.2    Mean   :2.146   Mean   :0.1604
 3rd Qu.: 68.75   3rd Qu.:395.8    3rd Qu.:3.000   3rd Qu.:0.0000
 Max.   : 70.00   Max.   :586.0    Max.   :6.000   Max.   :3.0000
 NA's   :210.00   NA's   :  2.0
  Grey.Beetle         Aphid             Ant         BlackOrangeWasp
 Min.   : 0.000   Min.   :  0.00   Min.   :0.0000   Min.   :0.0000
```

```
1st Qu.: 0.750   1st Qu.:  0.00   1st Qu.:0.0000   1st Qu.:0.0000
Median : 3.000   Median :  4.00   Median :0.0000   Median :0.0000
Mean   : 8.476   Mean   : 13.89   Mean   :0.2877   Mean   :0.0566
3rd Qu.:10.000   3rd Qu.: 16.00   3rd Qu.:0.0000   3rd Qu.:0.0000
Max.   :79.000   Max.   :174.00   Max.   :4.0000   Max.   :3.0000

 Syrphid.Fly      RedBlackFly      LargeHairyFly        Tiny.Fly
Min.   :0.0000   Min.   :0.00000   Min.   :0.00000   Min.   : 0.0000
1st Qu.:0.0000   1st Qu.:0.00000   1st Qu.:0.00000   1st Qu.: 0.0000
Median :0.0000   Median :0.00000   Median :0.00000   Median : 0.0000
Mean   :0.2075   Mean   :0.03302   Mean   :0.02358   Mean   : 0.6085
3rd Qu.:0.0000   3rd Qu.:0.00000   3rd Qu.:0.00000   3rd Qu.: 1.0000
Max.   :8.0000   Max.   :2.00000   Max.   :2.00000   Max.   :11.0000

 GreenTrueBug     SkinnyBlackFly    BlackYellowFly    TinyRedSpider
Min.   :0.00000   Min.   :0.00000   Min.   :0.00000   Min.   :0.000000
1st Qu.:0.00000   1st Qu.:0.00000   1st Qu.:0.00000   1st Qu.:0.000000
Median :0.00000   Median :0.00000   Median :0.00000   Median :0.000000
Mean   :0.02358   Mean   :0.08962   Mean   :0.01415   Mean   :0.009434
3rd Qu.:0.00000   3rd Qu.:0.00000   3rd Qu.:0.00000   3rd Qu.:0.000000
Max.   :1.00000   Max.   :3.00000   Max.   :2.00000   Max.   :1.000000

BrightGreenFly      GreyMoth         BlackWasp          GreyFly
Min.   :0.0000   Min.   :0.00000   Min.   :0.00000   Min.   :0.000000
1st Qu.:0.0000   1st Qu.:0.00000   1st Qu.:0.00000   1st Qu.:0.000000
Median :0.0000   Median :0.00000   Median :0.00000   Median :0.000000
Mean   :0.0283   Mean   :0.01415   Mean   :0.01887   Mean   :0.004717
3rd Qu.:0.0000   3rd Qu.:0.00000   3rd Qu.:0.00000   3rd Qu.:0.000000
Max.   :3.0000   Max.   :2.00000   Max.   :1.00000   Max.   :1.000000

MaroonHorseFly          Wasp          HumpbackFly          Thrips
Min.   :0.000000   Min.   :0.00000   Min.   :0.00000   Min.   :0.00000
1st Qu.:0.000000   1st Qu.:0.00000   1st Qu.:0.00000   1st Qu.:0.00000
Median :0.000000   Median :0.00000   Median :0.00000   Median :0.00000
Mean   :0.004717   Mean   :0.06132   Mean   :0.04717   Mean   :0.03302
3rd Qu.:0.000000   3rd Qu.:0.00000   3rd Qu.:0.00000   3rd Qu.:0.00000
Max.   :1.000000   Max.   :1.00000   Max.   :4.00000   Max.   :3.00000

  SkinnyBee          FruitFly          BrownFly          HoneyBee
Min.   :0.00000   Min.   :0.000000   Min.   :0.00000   Min.   :0.00000
1st Qu.:0.00000   1st Qu.:0.000000   1st Qu.:0.00000   1st Qu.:0.00000
Median :0.00000   Median :0.000000   Median :0.00000   Median :0.00000
Mean   :0.01887   Mean   :0.009434   Mean   :0.01887   Mean   :0.08019
```

```
3rd Qu.:0.00000   3rd Qu.:0.000000   3rd Qu.:0.00000   3rd Qu.:0.00000
Max.   :2.00000   Max.   :1.000000   Max.   :1.00000   Max.   :4.00000

BrightGreenBee      BigBlackFly       BlackGreyFly     SkinnyBlackBee
Min.   :0.000000   Min.   :0.00000   Min.   :0.00000   Min.   :0
1st Qu.:0.000000   1st Qu.:0.00000   1st Qu.:0.00000   1st Qu.:0
Median :0.000000   Median :0.00000   Median :0.00000   Median :0
Mean   :0.004717   Mean   :0.04245   Mean   :0.08019   Mean   :0
3rd Qu.:0.000000   3rd Qu.:0.00000   3rd Qu.:0.00000   3rd Qu.:0
Max.   :1.000000   Max.   :3.00000   Max.   :3.00000   Max.   :0

Microbutterfly    LongHornBeetle    RedThoraxBeetle      RedGreyFly
Min.   :0.00000   Min.   :0.00000   Min.   :0.000000   Min.   :0.000000
1st Qu.:0.00000   1st Qu.:0.00000   1st Qu.:0.000000   1st Qu.:0.000000
Median :0.00000   Median :0.00000   Median :0.000000   Median :0.000000
Mean   :0.01887   Mean   :0.03774   Mean   :0.004717   Mean   :0.004717
3rd Qu.:0.00000   3rd Qu.:0.00000   3rd Qu.:0.000000   3rd Qu.:0.000000
Max.   :1.00000   Max.   :2.00000   Max.   :1.000000   Max.   :1.000000

 Caterpillar       BrightGreenSpider  SkinnyBrownSpider  BlackWhiteFly
Min.   :0.000000   Min.   :0.000000   Min.   :0.000000   Min.   :0.00000
1st Qu.:0.000000   1st Qu.:0.000000   1st Qu.:0.000000   1st Qu.:0.00000
Median :0.000000   Median :0.000000   Median :0.000000   Median :0.00000
Mean   :0.004717   Mean   :0.009434   Mean   :0.009434   Mean   :0.02358
3rd Qu.:0.000000   3rd Qu.:0.000000   3rd Qu.:0.000000   3rd Qu.:0.00000
Max.   :1.000000   Max.   :1.000000   Max.   :1.000000   Max.   :3.00000

  Robber.Fly       OrangeYellowHairyBee MetallicBlueFly       Ladybug
Min.   :0.000000   Min.   :0.0000       Min.   :0.000000   Min.   :0.000000
1st Qu.:0.000000   1st Qu.:0.0000       1st Qu.:0.000000   1st Qu.:0.000000
Median :0.000000   Median :0.0000       Median :0.000000   Median :0.000000
Mean   :0.004717   Mean   :0.0283       Mean   :0.004717   Mean   :0.004717
3rd Qu.:0.000000   3rd Qu.:0.0000       3rd Qu.:0.000000   3rd Qu.:0.000000
Max.   :1.000000   Max.   :2.0000       Max.   :1.000000   Max.   :1.000000

BlackOrangeButterfly OrangeAbdomenFly   GreenCaterpillar   OrangeAbdomenFly.1
Min.   :0.000000     Min.   :0.000000   Min.   :0.000000   Min.   :0.000000
1st Qu.:0.000000     1st Qu.:0.000000   1st Qu.:0.000000   1st Qu.:0.000000
Median :0.000000     Median :0.000000   Median :0.000000   Median :0.000000
Mean   :0.009434     Mean   :0.004717   Mean   :0.004717   Mean   :0.004717
3rd Qu.:0.000000     3rd Qu.:0.000000   3rd Qu.:0.000000   3rd Qu.:0.000000
Max.   :1.000000     Max.   :1.000000   Max.   :1.000000   Max.   :1.000000
```

```
> colnames(data)
 [1] "Family"               "Individual"           "RandomNmbr"
 [4] "Population"           "Elk."                 "Notes"
 [7] "Florettes"            "Flors.per.stalk"      "Date.of.Flwr"
[10] "Date.of.Srvy"         "Total.Height.mm."     "Stalks"
[13] "Ramets"               "Grey.Beetle"          "Aphid"
[16] "Ant"                  "BlackOrangeWasp"      "Syrphid.Fly"
[19] "RedBlackFly"          "LargeHairyFly"        "Tiny.Fly"
[22] "GreenTrueBug"         "SkinnyBlackFly"       "BlackYellowFly"
[25] "TinyRedSpider"        "BrightGreenFly"       "GreyMoth"
[28] "BlackWasp"            "GreyFly"              "MaroonHorseFly"
[31] "Wasp"                 "HumpbackFly"          "Thrips"
[34] "SkinnyBee"            "FruitFly"             "BrownFly"
[37] "HoneyBee"             "BrightGreenBee"       "BigBlackFly"
[40] "BlackGreyFly"         "SkinnyBlackBee"       "Microbutterfly"
[43] "LongHornBeetle"       "RedThoraxBeetle"      "RedGreyFly"
[46] "Caterpillar"          "BrightGreenSpider"    "SkinnyBrownSpider"
[49] "BlackWhiteFly"        "Robber.Fly"           "OrangeYellowHairyBee"
[52] "MetallicBlueFly"      "Ladybug"              "BlackOrangeButterfly"
[55] "OrangeAbdomenFly"     "GreenCaterpillar"     "OrangeAbdomenFly.1"
> com = data[14:ncol(data)]
```

Remove singletons and doubletons.

```
> com = com[, apply(com, 2, sum) > 2]
> colnames(com)
 [1] "Grey.Beetle"          "Aphid"                "Ant"
 [4] "BlackOrangeWasp"      "Syrphid.Fly"          "RedBlackFly"
 [7] "LargeHairyFly"        "Tiny.Fly"             "GreenTrueBug"
[10] "SkinnyBlackFly"       "BlackYellowFly"       "BrightGreenFly"
[13] "GreyMoth"             "BlackWasp"            "Wasp"
[16] "HumpbackFly"          "Thrips"               "SkinnyBee"
[19] "BrownFly"             "HoneyBee"             "BigBlackFly"
[22] "BlackGreyFly"         "Microbutterfly"       "LongHornBeetle"
[25] "BlackWhiteFly"        "OrangeYellowHairyBee"
> ds = rep(1, nrow(com))
> com. = cbind(com, ds)
> pop = data[, 4]
> pop
  [1] FS FS FS FS FS FS FS FS FS
 [10] FS FS FS FS FS FS FS FS FS
 [19] FS FS FS FS FS FS FS FS FS
 [28] FS FS FS FS FS FS FS FS FS
```

```
 [37] FS      FS      FS      FS      FS      FS      FS      FS      FS
 [46] FS      FS      FS      FS      FS      FS      Ft Vall Ft Vall Ft Vall
 [55] Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall
 [64] Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall
 [73] Ft Vall Ft Vall Ft Vall Ft Vall Ft Vall Grnhs   Grnhs   Grnhs   Grnhs
 [82] Grnhs   Grnhs   Grnhs   Grnhs   Grnhs   Grnhs   Grnhs   Grnhs   Grnhs
 [91] Grnhs   Grnhs   Grnhs   Grnhs   Grnhs   Grnhs   Grnhs   Grnhs   K In
[100] K In    K In    K In    K In    K In    K In    K In    K In    K In
[109] K In    K In    K In    K In    K In    K In    K In    K In    K In
[118] K In    K In    K In    K In    K In    K In    K In    K In    K In
[127] K Out   K Out   K Out   K Out   K Out   K Out   K Out   K Out   K Out
[136] K Out   K Out   K Out   K Out   K Out   K Out   K Out   K Out   K Out
[145] K Out   K Out   K Out   K Out   K Out   K Out   K Out   K Out   K Out
[154] K Out   K Out   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli
[163] Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli
[172] K In    K In    K Out   K Out   Keeli   Keeli   Keeli   Keeli   Keeli
[181] Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli
[190] Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli   Keeli
[199] Thorpe  Thorpe  Thorpe  Thorpe  Thorpe  Thorpe  Thorpe  Thorpe  Thorpe
[208] Thorpe  Thorpe  Thorpe  Thorpe  Thorpe
Levels: FS Ft Vall Grnhs K In K Out Keeli Thorpe
```

```
> fam = data[, 1]
> fam[fam == "Thrope 5"] <- "Thorpe 5"
> elk = data[, 5]
> elk[elk == ""] = "No"
```

1.3. **Network Modeling.**

```
> com.list <- list()
> for (i in (1:length(unique(elk)))) {
+     com.list[[i]] <- com[elk == unique(elk)[i], ]
+ }
> names(com.list) <- unique(elk)
> net.list <- lapply(com.list, kendall.pairs, adj.method = "fdr",
+     alpha = 0.05, p.adj = FALSE)
> par(mfrow = c(1, 2), mar = c(2.4, 1.3, 1.5, 1.3), oma = c(0.2,
+     0.1, 0.2, 0.1), mar = c(2, 1, 2, 1))
> names(net.list) = c("No Elk", "Elk")
> net.list.reorder <- net.list[c(1, 2)]
> com.list.reorder <- com.list[c(1, 2)]
> for (i in (1:length(net.list))) {
+     v.col = apply(com.list.reorder[[i]], 2, sum)
+     v.col[v.col != 0] = "black"
+     v.col[v.col == 0] <- "lightgray"
```

```
+     gplot(abs(net.list.reorder[[i]]), gmode = "graph", vertex.cex = 3,
+         vertex.sides = 100, vertex.col = v.col, edge.lwd = (abs(net.list.reorder[[i]]) +
+             1)^5, edge.col = gray(0.1)[1], vertex.border = "grey",
+         mode = "circle", displaylabel = FALSE, label = 1:ncol(net.list.reorder[[i]]),
+         label.cex = 0.75)
+     title(main = names(net.list.reorder)[i], cex.main = 2)
+ }
> par(mfrow = c(1, 2), mar = c(2.4, 1.3, 1.5, 1.3), oma = c(0.2,
+     0.1, 0.2, 0.1), mar = c(2, 1, 2, 1))
> names(net.list) = c("No Elk", "Elk")
> net.list.reorder <- net.list[c(1, 2)]
> com.list.reorder <- com.list[c(1, 2)]
> for (i in (1:length(net.list))) {
+     v.col = apply(com.list.reorder[[i]], 2, sum)
+     v.col[v.col != 0] = "black"
+     v.col[v.col == 0] <- "lightgray"
+     gplot(abs(net.list.reorder[[i]]), gmode = "graph", vertex.cex = 3,
+         vertex.sides = 100, vertex.col = v.col, edge.lwd = (abs(net.list.reorder[[i]]) +
+             1)^5, edge.col = gray(0.1)[1], vertex.border = "grey",
+         displaylabels = TRUE, label = 1:ncol(net.list.reorder[[i]]),
+         label.cex = 0.75)
+     title(main = names(net.list.reorder)[i], cex.main = 2)
+ }
```

Network Graphs.

Corresponding Species Labels.

```
 [1] "Grey.Beetle = 1"           "Aphid = 2"
 [3] "Ant = 3"                   "BlackOrangeWasp = 4"
 [5] "Syrphid.Fly = 5"           "RedBlackFly = 6"
 [7] "LargeHairyFly = 7"         "Tiny.Fly = 8"
 [9] "GreenTrueBug = 9"          "SkinnyBlackFly = 10"
[11] "BlackYellowFly = 11"       "BrightGreenFly = 12"
[13] "GreyMoth = 13"             "BlackWasp = 14"
[15] "Wasp = 15"                 "HumpbackFly = 16"
[17] "Thrips = 17"               "SkinnyBee = 18"
[19] "BrownFly = 19"             "HoneyBee = 20"
[21] "BigBlackFly = 21"          "BlackGreyFly = 22"
[23] "Microbutterfly = 23"       "LongHornBeetle = 24"
[25] "BlackWhiteFly = 25"        "OrangeYellowHairyBee = 26"
```

Network Structural Statistics.

```
> L <- unlist(lapply(net.list, function(x) bin.sum(x)/2))
> L
```

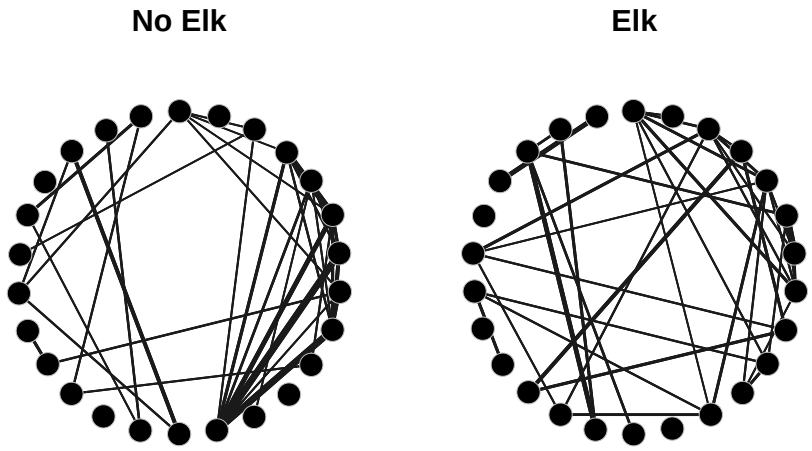

FIGURE 1. Network graph for elk and no elk exposed solidago offspring arranged in circle. Points represent species and lines represent statistically significant Kendall's tau correlation coefficients.

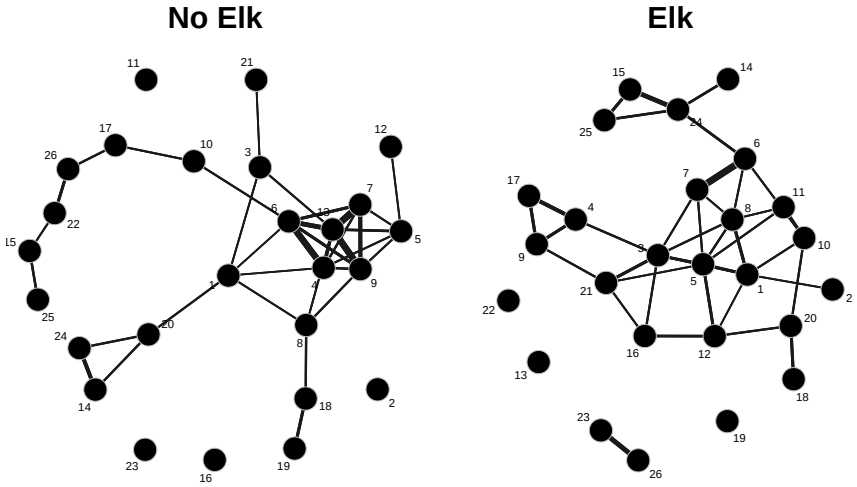

FIGURE 2. Network graph for elk and no elk exposed solidago offspring arranged using a physical force algorithm. Points represent species and lines represent statistically significant Kendall's tau correlation coefficients.

```
No Elk    Elk
    35     38
```

```
> unlist(lapply(net.list, function(x) centralization(x, degree)))
```

```
    No Elk        Elk
0.09895807 0.04954227
```

```
> unlist(lapply(net.list, fragmentation))
```

```
   No Elk       Elk
0.2892308 0.3507692
```

```
> ptc <- sort(apply(abs(net.list[[1]] - net.list[[2]]), 1, sum),
+     decreasing = TRUE)/sum(apply(abs(net.list[[1]] - net.list[[2]]),
+     1, sum)) * 100
> ptc
```

```
            GreyMoth         GreenTrueBug          RedBlackFly
           8.5564099            7.6639446            7.3241704
     BlackOrangeWasp          Syrphid.Fly        LargeHairyFly
           7.1767130            6.5168884            6.1632590
            Tiny.Fly                  Ant          Grey.Beetle
           5.6600643            5.2391345            5.0294040
            HoneyBee       LongHornBeetle              Thrips
           4.5365880            4.4610636            3.7685182
OrangeYellowHairyBee       SkinnyBlackFly            SkinnyBee
           3.3159858            2.9539405            2.8719922
      BrightGreenFly          BigBlackFly                 Wasp
           2.6241726            2.4213050            2.3077912
         HumpbackFly       BlackYellowFly         BlackGreyFly
           2.2338768            2.1914097            1.6024119
      Microbutterfly            BlackWasp        BlackWhiteFly
           1.5549120            1.1540013            1.1011539
            BrownFly                Aphid
           1.0648678            0.5060215
```

Barplots of Network Statistics.

```
> barplot(L, ylab = "Number of Connections", col = 1)
```

```
> barplot(unlist(lapply(net.list, function(x) centralization(x,
+     degree))), ylab = "Centralization", col = 1)
```

```
> barplot(unlist(lapply(net.list, fragmentation)), ylab = "Fragmentation",
+     col = 1)
```

```
> barplot(ptc, las = 2, col = "black", ylab = "Percent Total Change",
+     names = 1:length(ptc))
```

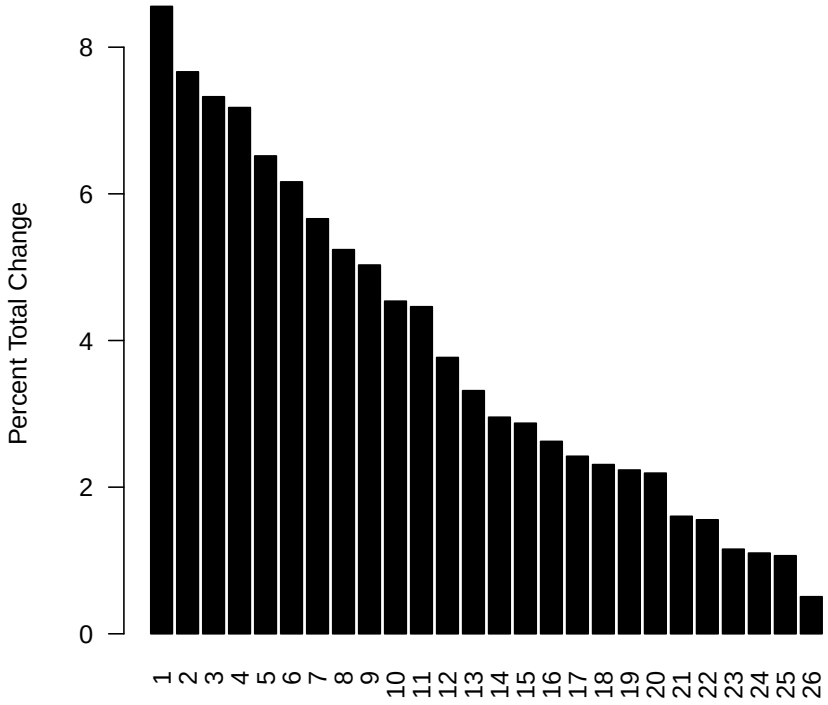

FIGURE 3. Barplot of the percent total change in connections (PTC) comparing **Elk** and **No Elk** exposed solidago.

Corresponding Species Labels for PTC Plot.

```
 [1] "GreyMoth"              "GreenTrueBug"          "RedBlackFly"
 [4] "BlackOrangeWasp"       "Syrphid.Fly"           "LargeHairyFly"
 [7] "Tiny.Fly"              "Ant"                   "Grey.Beetle"
[10] "HoneyBee"              "LongHornBeetle"        "Thrips"
[13] "OrangeYellowHairyBee" "SkinnyBlackFly"        "SkinnyBee"
[16] "BrightGreenFly"        "BigBlackFly"           "Wasp"
[19] "HumpbackFly"           "BlackYellowFly"        "BlackGreyFly"
[22] "Microbutterfly"        "BlackWasp"             "BlackWhiteFly"
[25] "BrownFly"              "Aphid"
```

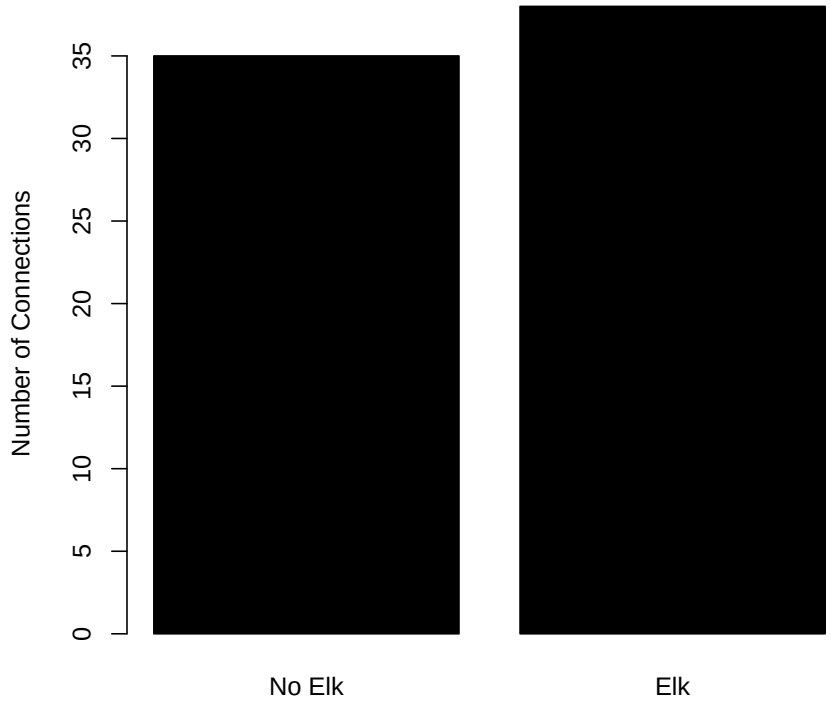

FIGURE 4. Barplot of the number of connetions in each graph.

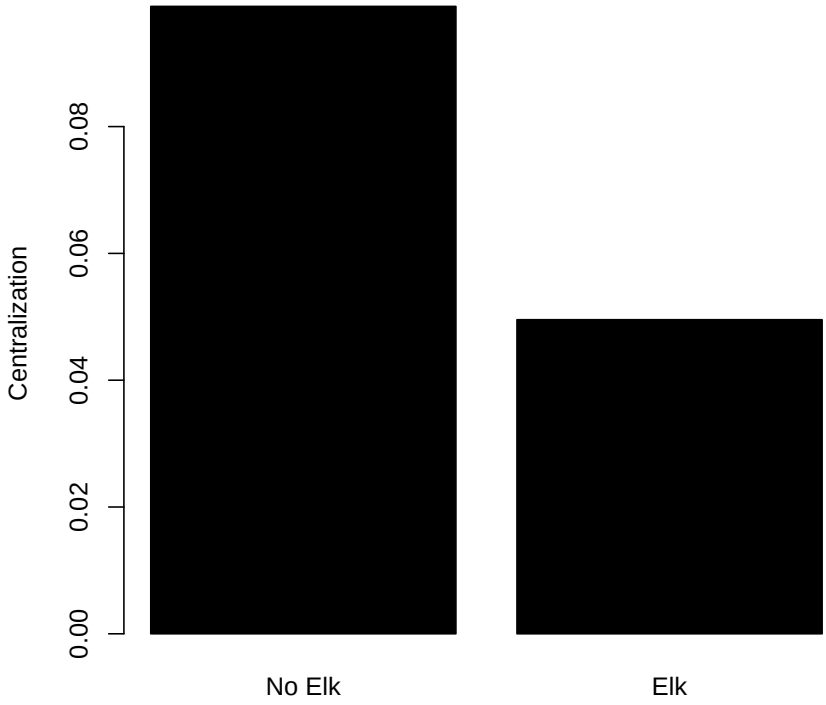

FIGURE 5. Barplot of the centralization of each graph.

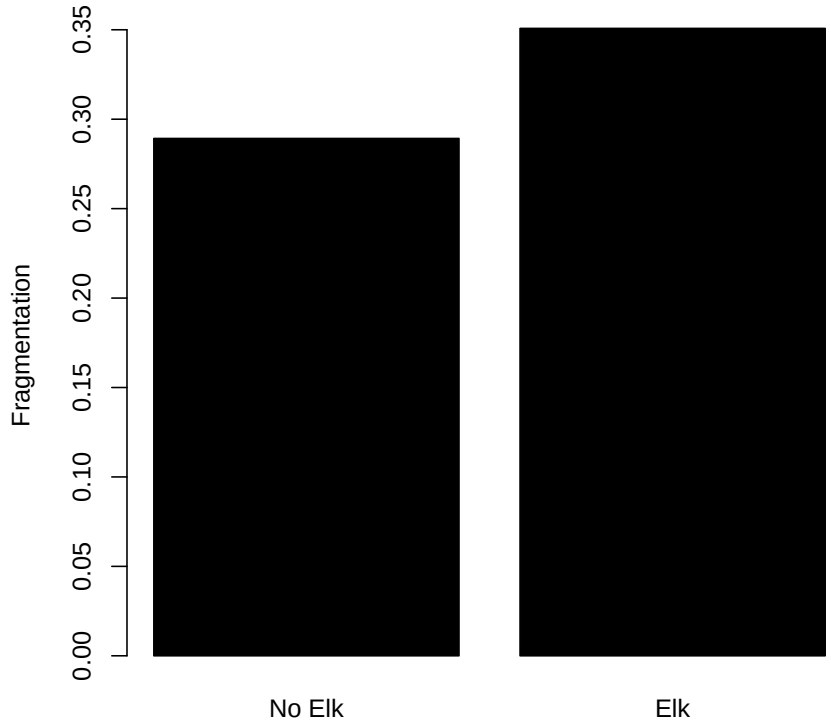

FIGURE 6. Barplot of the fragmentation of each graph.