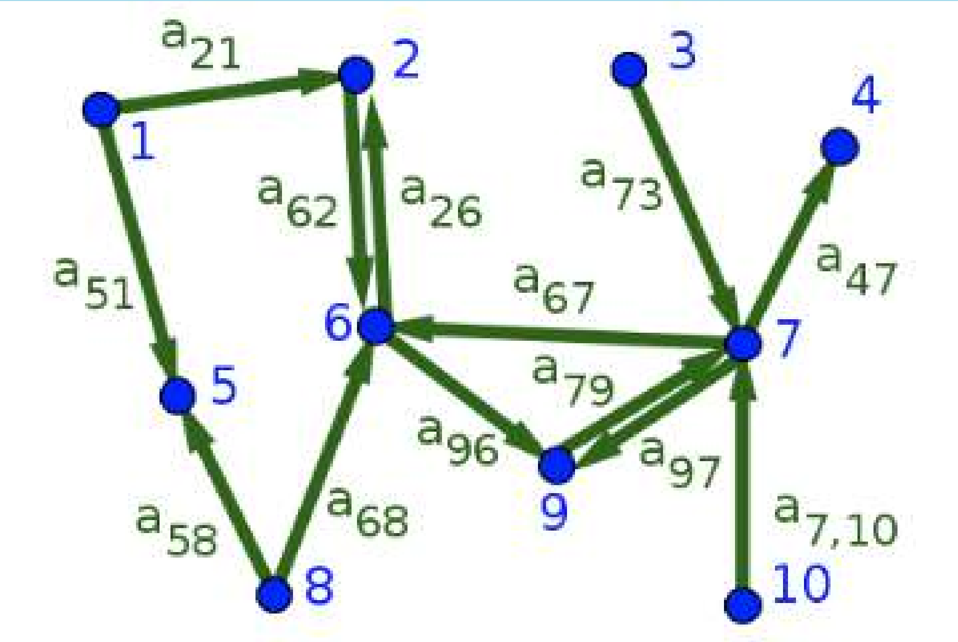
Movement and Networks II

HES 505 Fall 2023: Session 26

Matt Williamson

Describing networks for analysis



$$A = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Common measures

- Graph-level: density, diameter, distance
- Component-level: density, distribution
- Node-level: centrality, degree-distribution

Common questions

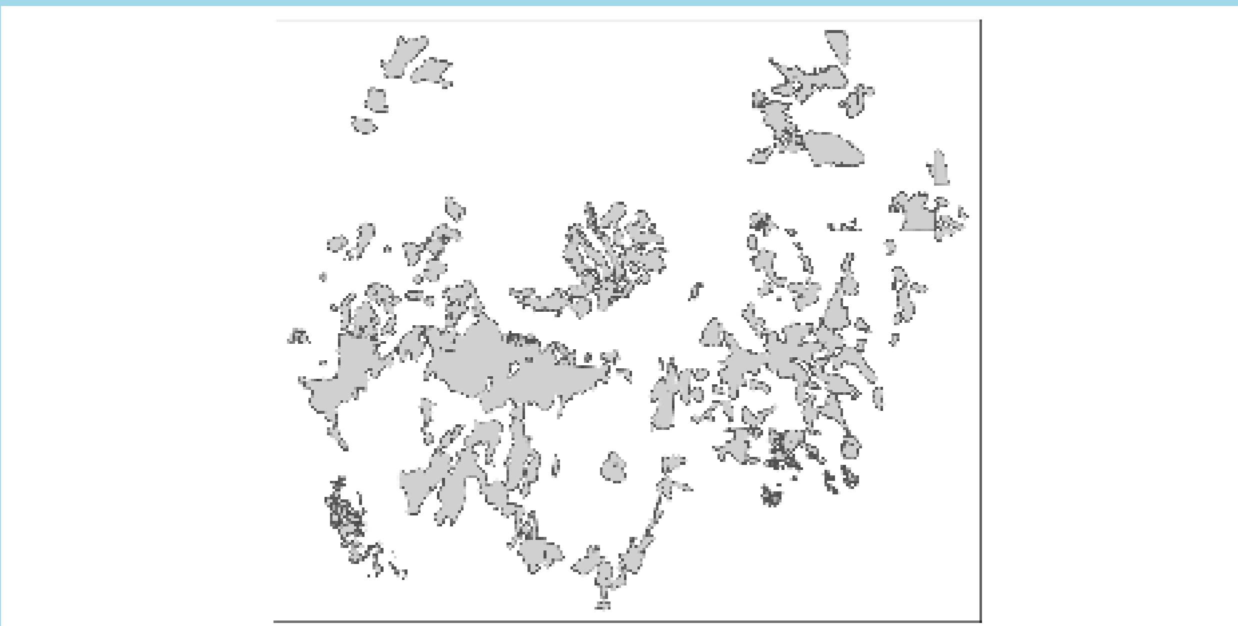
- What are the shortest paths across the network?
- Where are the most important locations for maintaining the network?
- How does the loss of a node alter the subsequent configuration of the network?
- How do we translate typical movement paths into network structures?

An example

Sage Grouse in the West

```
Reading layer `GRSG_2015_USFWS_StatusReview_PACs' from data source

`/Users/mattwilliamson/Websites/isdrfall23/slides/data/GRSG_2015_USFWS_StatusRe
  using driver `ESRI Shapefile'
Simple feature collection with 301 features and 9 fields
Geometry type: POLYGON
Dimension:     XY
Bounding box:  xmin: -1361708 ymin: 381165.6 xmax: 147308.4 ymax: 1661769
Projected CRS: GRSG Range Wide
```



The Data

```r
head(sg.pacs[,1:9])
```

```
Simple feature collection with 6 features and 9 fields
Geometry type: POLYGON
Dimension:     XY
Bounding box:  xmin: -1183048 ymin: 446911.4 xmax: -1096618 ymax: 472038.5
Projected CRS: GRSG Range Wide
  OBJECTID UniqueID Population MgmtZone           ID_Name     Acres Shape_Leng
1        1      401   Bi-State      MZ3 401-Bi-State-MZ3  444.2940   5691.176
2        2      362   Bi-State      MZ3 362-Bi-State-MZ3 3553.0707  25207.100
3        3      400   Bi-State      MZ3 400-Bi-State-MZ3  494.7130   5958.419
4        4      399   Bi-State      MZ3 399-Bi-State-MZ3  995.5216  10911.550
5        5      398   Bi-State      MZ3 398-Bi-State-MZ3  395.0896   7904.861
6        6      361   Bi-State      MZ3 361-Bi-State-MZ3 8252.1309  60989.117
  Shape_Area Bi_State                       geometry
1    1797994      Yes POLYGON ((-1181624 457935.6...
2   14378767      Yes POLYGON ((-1102151 456210.8...
```

Preparing the adjacency matrix

```
sg.pacs.cent <- sg.pacs %>%
  filter(., MgmtZone == "MZ3") %>%
  st_centroid(sg.pacs, of_largest_polygon = TRUE)
```

Preparing the Adjacency Matrix

```
sg.pacs.dist <- st_distance(sg.pac

threshold <- units::as_units(50, "

adj.mtx <- sg.pacs.dist < threshol
```

```
      1     2     3     4     5
1  TRUE FALSE FALSE FALSE FALSE
2 FALSE  TRUE  TRUE  TRUE  TRUE
3 FALSE  TRUE  TRUE  TRUE  TRUE
4 FALSE  TRUE  TRUE  TRUE  TRUE
5 FALSE  TRUE  TRUE  TRUE  TRUE
```

Preparing the Adjacency Matrix

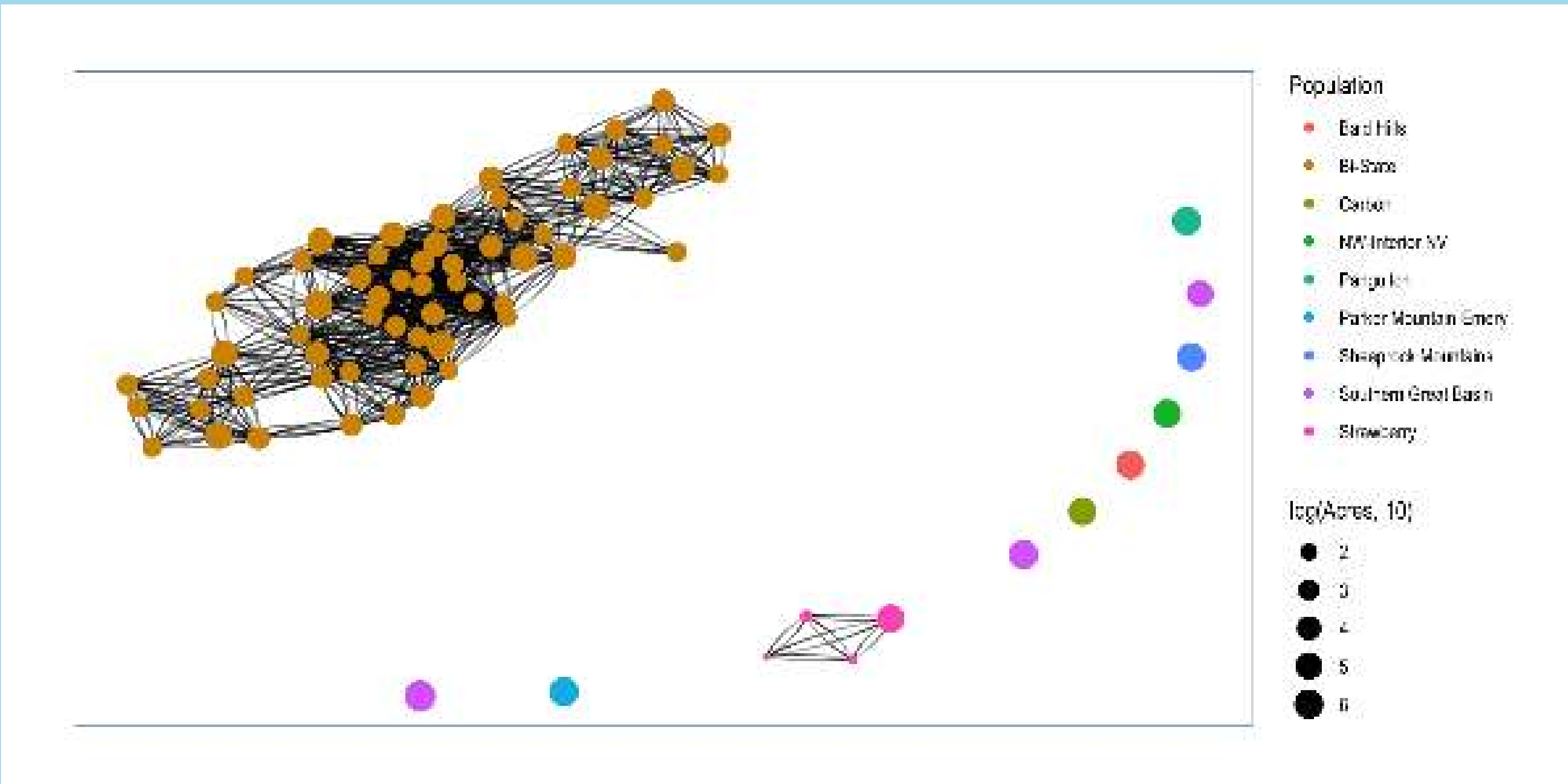
```r
adj.mtx <- adj.mtx *1
diag(adj.mtx) <- 0

dimnames(adj.mtx) <- list(
  sg.pacs.cent$UniqueID,
  sg.pacs.cent$UniqueID)
```

```
    401 362 400 399 398
401   0   0   0   0   0
362   0   0   1   1   1
400   0   1   0   1   1
399   0   1   1   0   1
398   0   1   1   1   0
```

Graphing your network

```
sg.graph <- igraph::graph_from_adjacency_matrix(adj.mtx) %>%
  as_tbl_graph(directed - FALSE,
                  node_key = "UniqueID") %>%
  left_join(., sg.pacs.cent,
              by = c("name" = "UniqueID"))
```



Evaluating Network Metrics

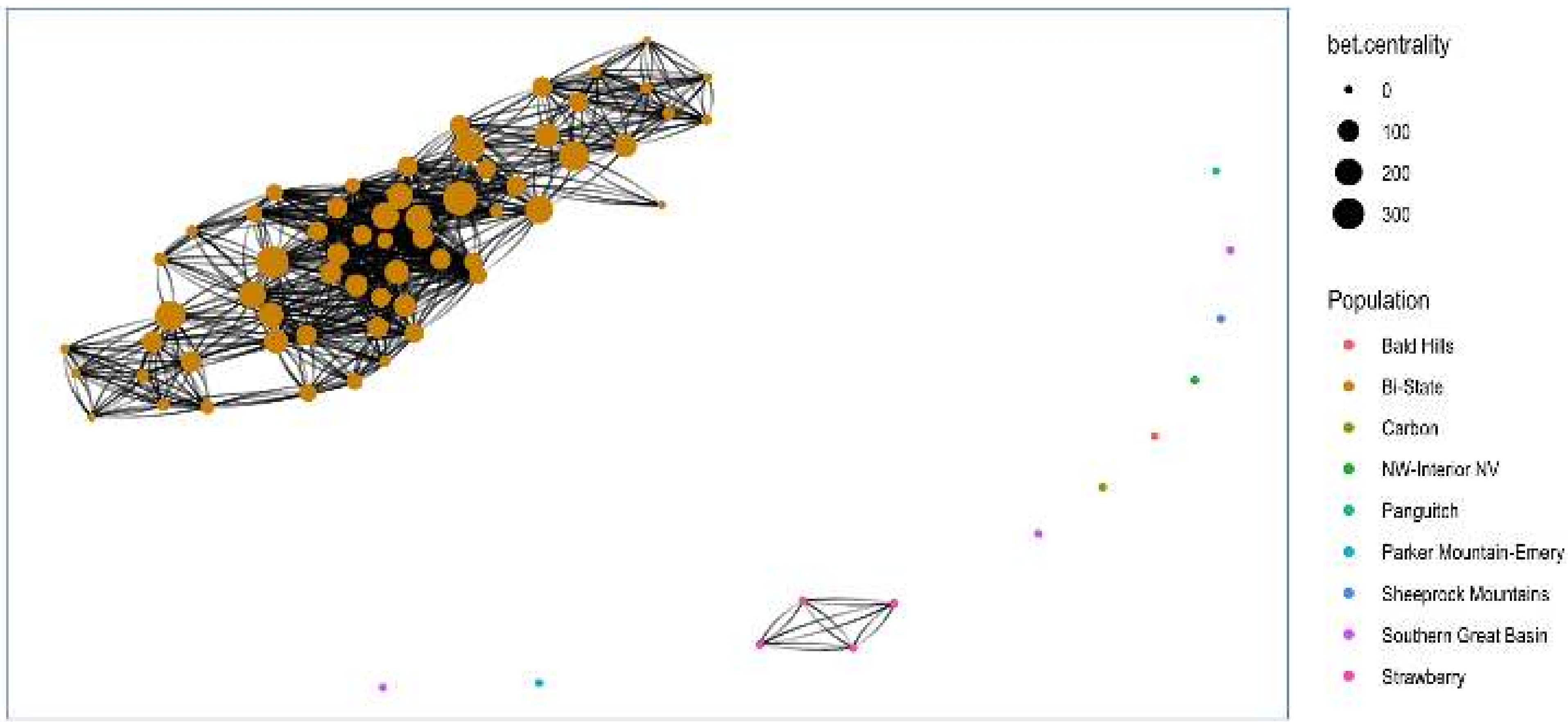
Common Metrics

- **Betweenness Centrality**: the sum of all of the shortest paths that flow through that node.
- **Degree** reflects the number of connections a node has to other nodes.
- **Component size**: the number of nodes in a group that is connected to each other, but disconnected from the rest of the graph
- **Degree Distribution**: Describes the general connectedness of all the nodes in a network; vulnerability

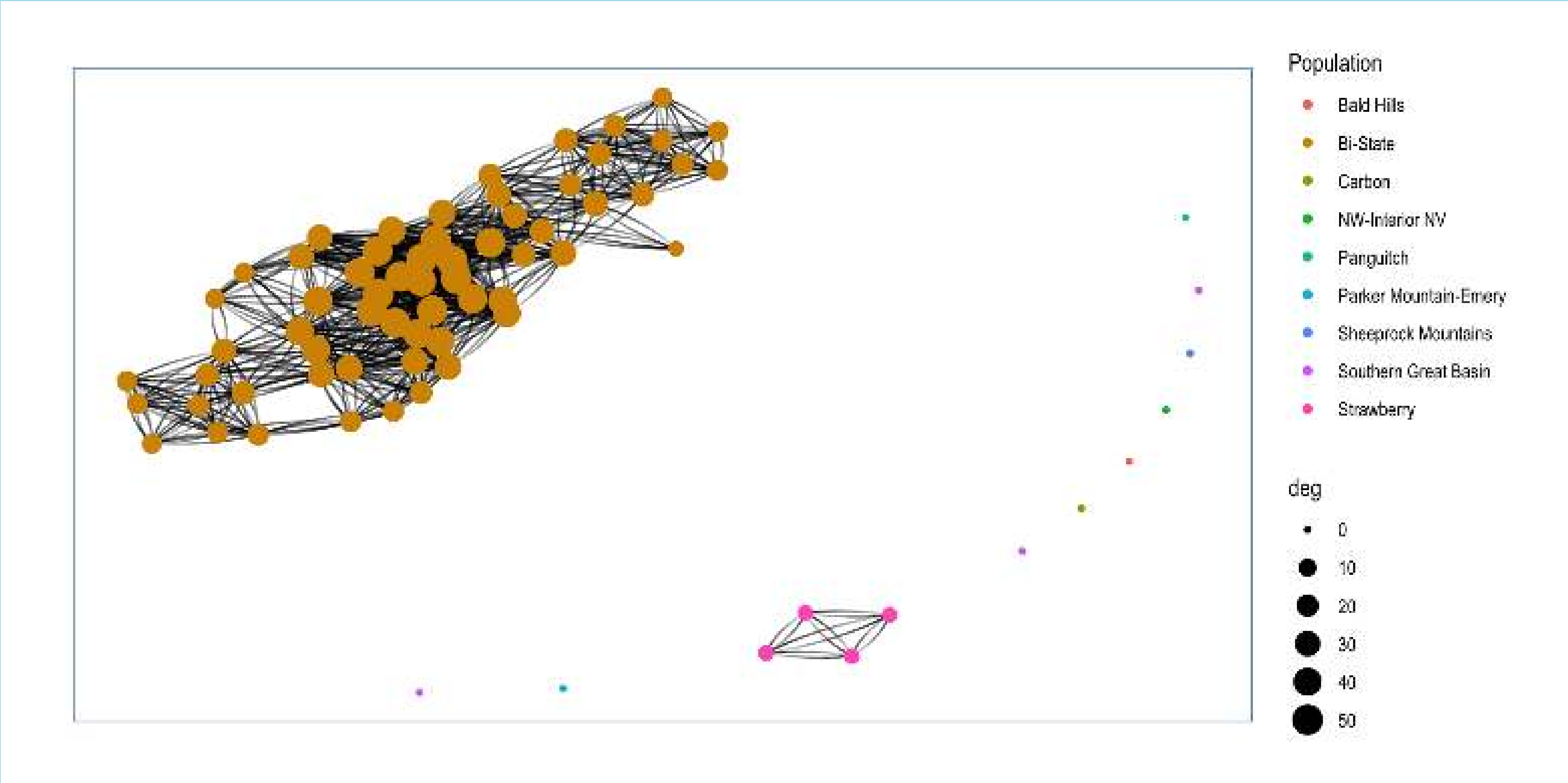
Estimating metrics

```
sg.graph.mets <- sg.graph %>%
  activate(nodes) %>%
  mutate(., bet.centrality = centrality_betweenness(),
            deg = degree(.))
```

Estimating metrics: Betweeness



Estimating metrics: Degree



Estimating metrics: Component Size

```r
comps <- components(sg.graph)
comps$csize
```

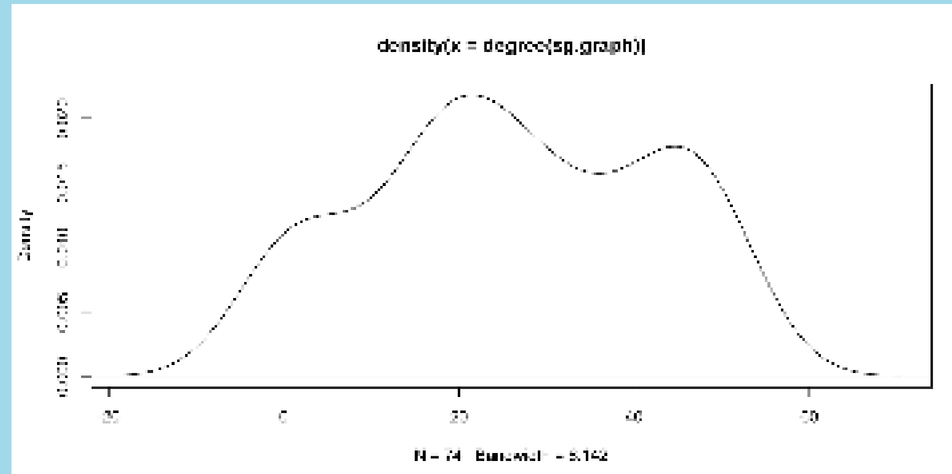
```
 [1] 61  1  1  1  1  1  4  1  1  1  1
```

```r
comps$membership
```

```
401 362 400 399 398 361 360 397 359 396 395 358 353 394 393 392 357 354 355
352
  1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
351 350 391 390 389 388 356 387 386 385 349 384 383 382 381 380 379 378 377
376
  1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1
375 374 239 347 345 373 372 348 371 346 370 369 368 344 367 366 365 364 343
242
  1   1   2   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
3
342 363 341 238 237 241 234 232 235 236 233 244 243 240
  1   1   1   4   5   6   7   8   7   7   7   9  10  11
```

Estimating metrics: Degree distribution

```
[1] 26.10811
[1] 16.13943
```



Experimenting

Setting up the data

```r
thresholds <- as_units(c(1, 10,25, 50, 100, 150, 250, 500), "km")
thresh.df <- data.frame(thresh.dist = rep(NA, length(thresholds)),
                        mean.between = rep(NA, length(thresholds)),
                        ncomps = rep(NA, length(thresholds)),
                        mean.deg = rep(NA, length(thresholds)))
sg.pacs.cent <- sg.pacs %>%
  st_centroid(sg.pacs, of_largest_polygon = TRUE)
sg.pacs.dist <- st_distance(sg.pacs.cent)
```

Iterating

```r
for (i in 1:length(thresholds)){
  adj.mtx <- sg.pacs.dist < thresholds[i]
  adj.mtx <- adj.mtx *1
  diag(adj.mtx) <- 0
  dimnames(adj.mtx) <- list(sg.pacs.cent$UniqueID, sg.pacs.cent$UniqueID)

  sg.graph <- igraph::graph_from_adjacency_matrix(adj.mtx) %>%
  as_tbl_graph(directed - FALSE,
               node_key = "UniqueID") %>%
  left_join(., sg.pacs.cent,
            by = c("name" = "UniqueID"))
  thresh.df$thresh.dist[i] <- thresholds[i]
  thresh.df$mean.between[i] <- mean(betweenness(sg.graph, directed = FALSE)
  thresh.df$ncomps[i] <- length(components(sg.graph)$csize)
  thresh.df$mean.deg[i] <- mean(degree(sg.graph))
}
```

Collecting Data

```r
thresh.long <- thresh.df %>%
  tidyr::pivot_longer(!thresh.dist,
                      names_to = "metric",
                      values_to = "estimate")

ggplot(data = thresh.long, aes(x= thresh.dist, y = estimate)) +
  geom_line()+
  facet_wrap(vars(metric)) +
  ggtitle("Whole Network")
```