

Population Graphs

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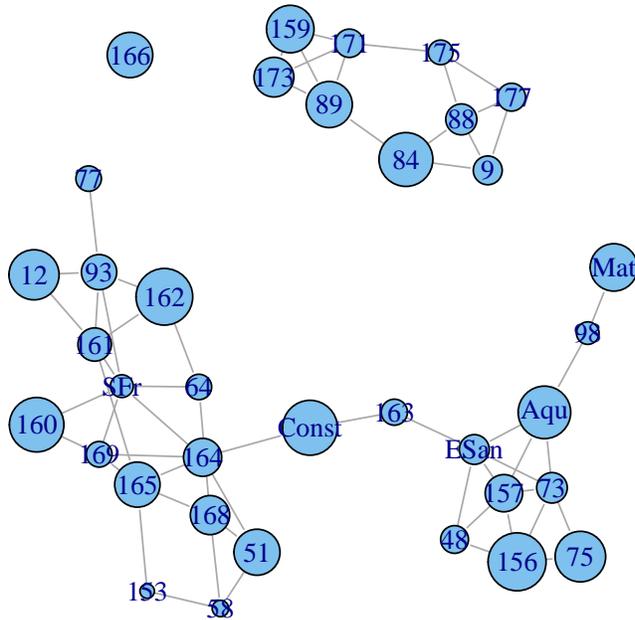
Synopsis

A population graph is a topological representation of within and among population genetic variance first introduced by Dyer & Nason (2004). It is particularly well suited to characterizing how spatial genetic variation is distributed among sites.

```
> require(gstudio)
> data(araptus_attenuatus)
> baja <- araptus_attenuatus[araptus_attenuatus$Species != "CladeB",
+ ]
```

Simple Population Graphs

```
> graph <- population.graph(baja, "Pop")
transforming data... done
Rotating mv genos and partitioning... done
Estimating conditional genetic covariance... done
> summary(graph)
Vertices: 36
Edges: 59
Directed: FALSE
No graph attributes.
Vertex attributes: name, size.
Edge attributes: weight.
> l <- layout.fruchterman.reingold(graph)
> plot(graph, layout = l, vertex.label = V(graph)$name)
```



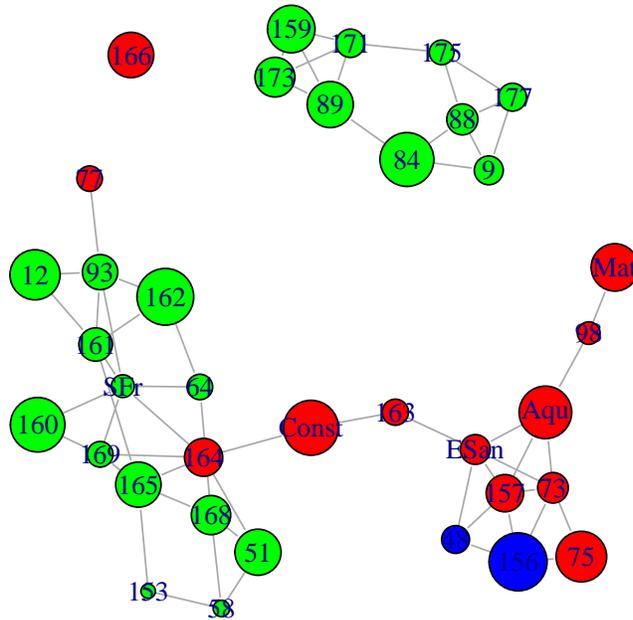
We know that these data are a mixture of two putative species denoted as CladeA and CladeC.

```
> table(baja$Species)
```

```
CladeA CladeC
  75     252
```

We can color the nodes depending upon the identity of clade representation at the node-level. If there is a mixture of species, you would expect to find that the mixed populations would be topologically intermediate between populations made up of pure samples.

```
> getCladeColor <- function(pop, data) {
+   inds <- data$Species[data$Pop == pop]
+   levels.inds <- levels(as.factor(as.character(inds)))
+   if (length(levels.inds) == 2)
+     return("red")
+   else if (levels.inds == "CladeA")
+     return("blue")
+   else return("green")
+ }
> colors <- unlist(lapply(V(graph)$name, function(x) getCladeColor(x,
+   baja)))
> plot(graph, layout = 1, vertex.label = V(graph)$name, vertex.color = colors)
```



So if we only use the samples from CladeC we may be actually analyzing the data in a way that makes sense. Do this by:

1. Use only the CladeC individuals
2. Get rid of the populations with say $N < 5$ individuals
3. Make graph and examine the topology

```
> baja.cladeC <- baja[baja$Species == "CladeC", ]
> inds.per.pop <- lapply(partition(baja.cladeC, "Pop"), function(x) dim(x)[1])
> smPops <- c("Const", "ESan", "157", "73", "Aqu", "Mat", "98",
+           "75")
> baja.cladeC <- baja.cladeC[!(baja.cladeC$Pop %in% smPops), ]
> graph.cladeC <- population.graph(baja.cladeC, "Pop")
```

transforming data... done

Rotating mv genos and partitioning... done

Estimating conditional genetic covariance... done

```
> summary(graph.cladeC)
```

Vertices: 26

Edges: 33

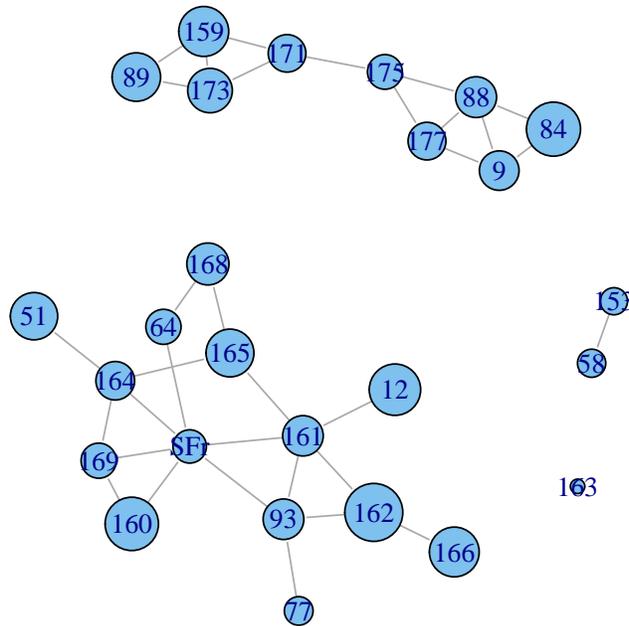
Directed: FALSE

No graph attributes.

Vertex attributes: name, size.

Edge attributes: weight.

```
> l <- layout.fruchterman.reingold(graph.cladeC)
> plot(graph.cladeC, layout = l, vertex.label = V(graph.cladeC)$name)
```

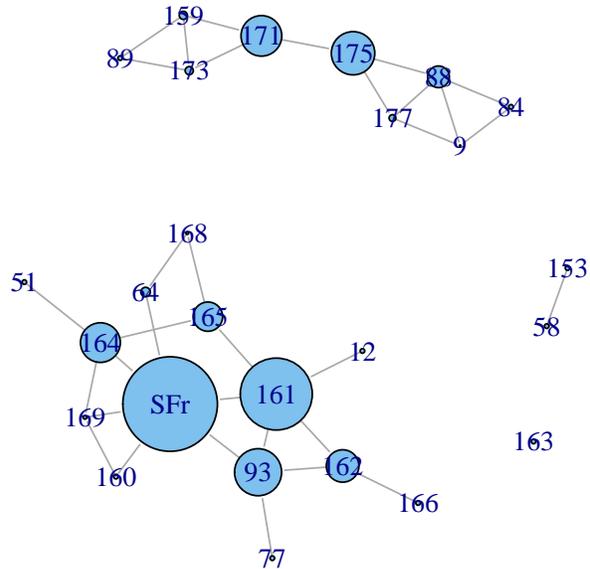


From this plot, you can see even when we only focus on the true CladeC individuals, there is still partitioning of genetic covariance!

Node Position

Both node and edge position in the topology can easily be determined using common network analysis tools. The `igraph` package has some as does the most excellent `sna` package. Here is a quick example where the size of the node is depicting the node's betweenness (e.g., the number of shortest paths that go through that node).

```
> pop.betweenness <- betweenness(graph.cladeC, directed = F)
> plot(graph.cladeC, layout = l, vertex.label = V(graph.cladeC)$name,
+      vertex.size = pop.betweenness)
```



Which is rather interesting since betweenness can be used to classify relative population importance. Presently, it is common to use genetic diversity as a surrogate to identify populations of high conservation importance, but betweenness relates to the connectivity of the gene flow topology on the landscape and is not necessarily correlated with genetic diversity.

```
> cor.test(V(graph.cladeC)$size, pop.betweenness, method = "spearman")
```

```
Spearman's rank correlation rho
```

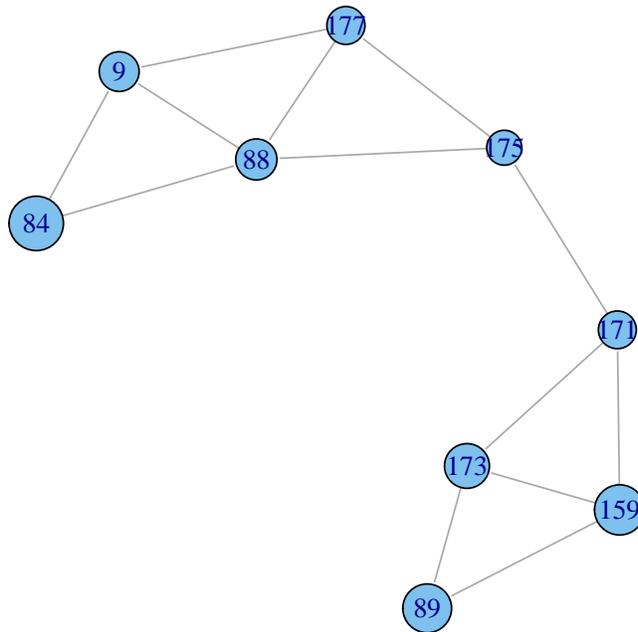
```
data: V(graph.cladeC)$size and pop.betweenness
S = 3259.634, p-value = 0.5779
alternative hypothesis: true rho is not equal to 0
sample estimates:
rho
-0.1144049
```

Conditional Genetic Distance

In Dyer *et al.* (2010) we showed that graph distance (e.g., the shortest path connecting points in the topology) was more powerful than pair-wise structure and distance approaches. We denoted the among population distance as *cGD* for conditional graph distance.

Since this topology is disconnected, we'll just focus on the medium sized component, the one with 84 in it.

```
> connected.to.84 <- subcomponent(graph.cladeC, v = "84")
> med.graph <- subgraph(graph.cladeC, v = connected.to.84)
> med.layout <- layout.fruchterman.reingold(med.graph)
> plot(med.graph, layout = med.layout, vertex.label = V(med.graph)$name)
> D <- shortest.paths(med.graph)
```



As discussed previously, we can also get the pair-wise physical distance and then examine "Isolation by Graph Distance" (IBGD), which has some nice properties that make it perhaps more precise than IBD based upon pair-wise structure estimates.

```
> pops <- V(med.graph)$name
> coords <- lapply(pops, function(pop) {
+   c(mean(baja$Long[baja$Pop == pop]), mean(baja$Lat[baja$Pop ==
+     pop]))
+ })
> coords <- matrix(unlist(coords), ncol = 2, byrow = T)
> coords
```

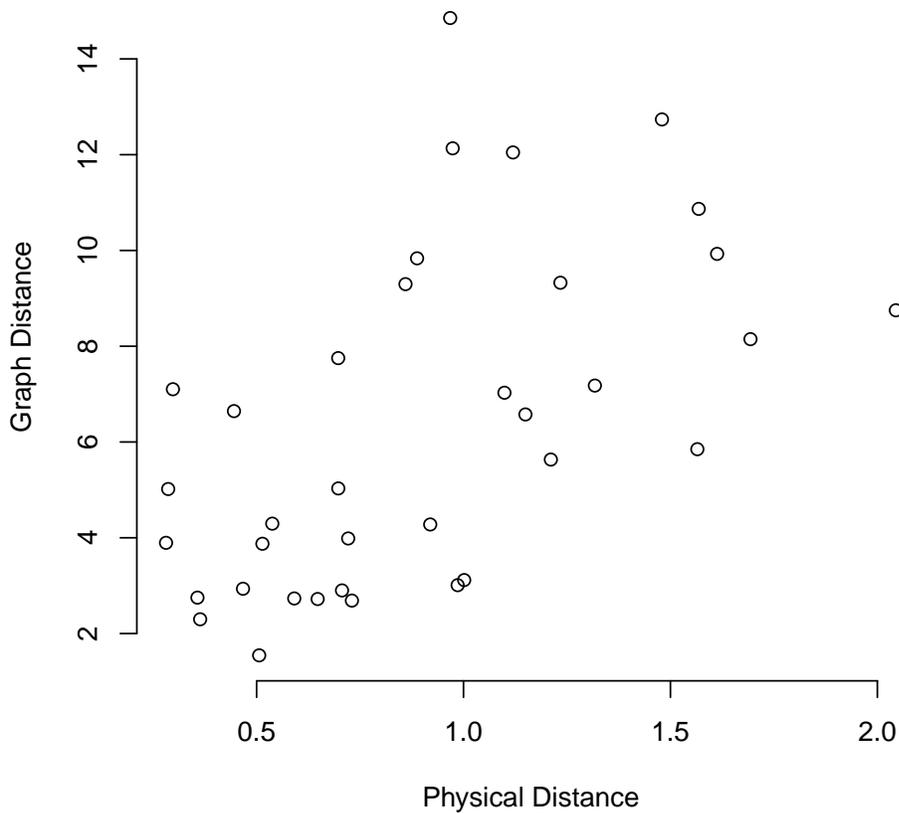
```
      [,1]      [,2]
[1,] -113.3161 27.52944
[2,] -113.1826 28.22308
[3,] -112.8698 28.40846
```

```

[4,] -113.4897 28.72796
[5,] -113.9914 28.66056
[6,] -113.6679 28.96651
[7,] -114.2935 29.32541
[8,] -113.3999 28.03661
[9,] -113.9449 29.01457

> require(fields, quietly = T)
> P <- rdist(coords)
> plot(D[lower.tri(D)] ~ P[lower.tri(P)], bty = "n", xlab = "Physical Distance",
+      ylab = "Graph Distance")

```



We can use a Mantel test to see if there is a correlation between graph and physical distance for this subcomponent.

```

> require(ecodist, quietly = T)
> mantel(as.dist(D) ~ as.dist(P))

  mantelr      pval1      pval2      pval3  llim.2.5% ulim.97.5%
0.5571358 0.0060000 0.9950000 0.0060000 0.4704815 0.6979826

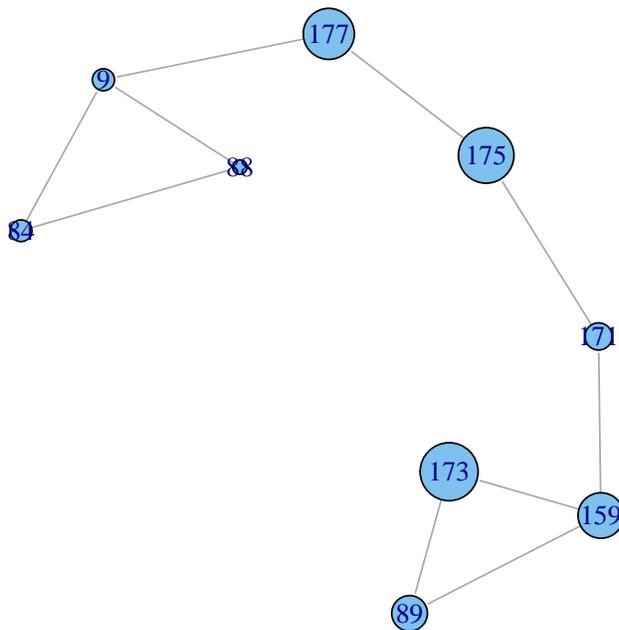
```

The pval3 is the probability of $H_0 : Mantel\rho = 0$.

Graph Partitions

A very important point needs to be made here regarding subgraphs and partitions of the whole data set. The disconnected subgraph in the previous section is not necessarily the same graph you would get if you partitioned the genotypes into only those populations and then make the graph. Compare the previous network topology to this one.

```
> tmp.pop <- baja[baja$Pop %in% c("9", "84", "88", "89", "159",  
+   "171", "173", "175", "177")]  
> tmp.graph <- population.graph(tmp.pop, "Pop")  
  
transforming data... done  
Rotating mv genos and partitioning... done  
Estimating conditional genetic covariance... done  
  
> plot(tmp.graph, layout = med.layout, vertex.label = V(tmp.graph)$name)
```



This is because Population Graphs are constructed using *Conditional Genetic Covariance*. The genetic covariance between populations 173 & 171 is conditional on their covariance with all the other data in the data set. In the first graph this includes the populations in this subgraph as well as the populations outside the subgraph.