

Mapping Protocol

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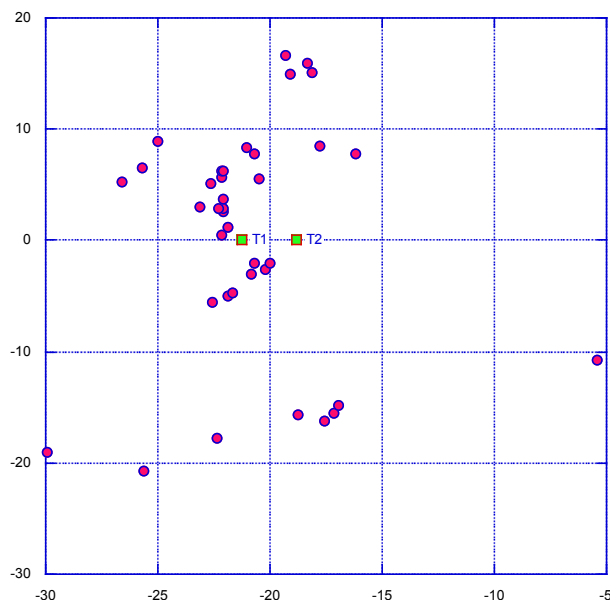
In the field, I faced the challenge of creating a map of a population of over 400 individuals that spanned over 300 meters of mountainous terrain. Large obstacles such as trees, large bushes, and boulders obscured the view of most plants from any single vantage point. Thus, I first mapped smaller parts of the population where all plants in a given area could be seen, and then subsequently linked these smaller maps together into a single large map. Small maps were linked together by having a few plants mapped in both. Below is the triangulation process I used to map plants in each smaller section of the population as well as the process I used to subsequently create a single x-y coordinate system with every plant in order to obtain relative distances for spatial analyses.

1. Collecting Data in the Field A. Setting up Targets

- i. Set up two “targets” so that they every plant has an unobstructed view of each target. We used Leica reflective target plates mounted on tripods. We then used a Leica laser distance meter to determine the distance between targets. This variable is **Target Distance**, or **TD**. It is important to record the relative positions of these targets to the plants for spatial analyses. For example, if targets are above plants the final y-coordinates will be negative.
- ii. As you can see below, some of the plants are above the targets and some are below. It is important to note this in the field so the graph is oriented correctly.



TG Example with plants on both sides of Targets



- iii. For each plant in the group, we then used the laser to obtain distances to **Target 1** and **Target 2**. These variables are **T1** and **T2**.
- iv. Repeat for all plants in the area.

B. Linking Target Groups in the Field

- i. Repeat step **1-A-i** for another group of nearby plants.
- ii. From at least 2 plants in the previous group, measure the distance to the NEW **Target 1** and **Target 2**. This could also be done for any objects that can be mapped using both target groups. This allows one to link the different target groups together later (see below).

- C. Repeat steps **1-A** and **1-B** until all plants have been mapped in at least one target group.

2. Converting Measurements into x-y Coordinates

A. Equations

$$x = \frac{(T1^2 - T2^2) + TD^2}{2(TD)}$$

$$y = \pm\sqrt{T1^2 - x^2}$$

- B. To obtain x and y coordinates, the above equation was applied to an entire Microsoft Excel Spreadsheet.

- i. It is important to note whether targets (**1-A-i**) are above or below the group of plants. The location determines if the y-coordinate is positive or negative, which will change the shape of the final map.

3. Graphing Target Groups

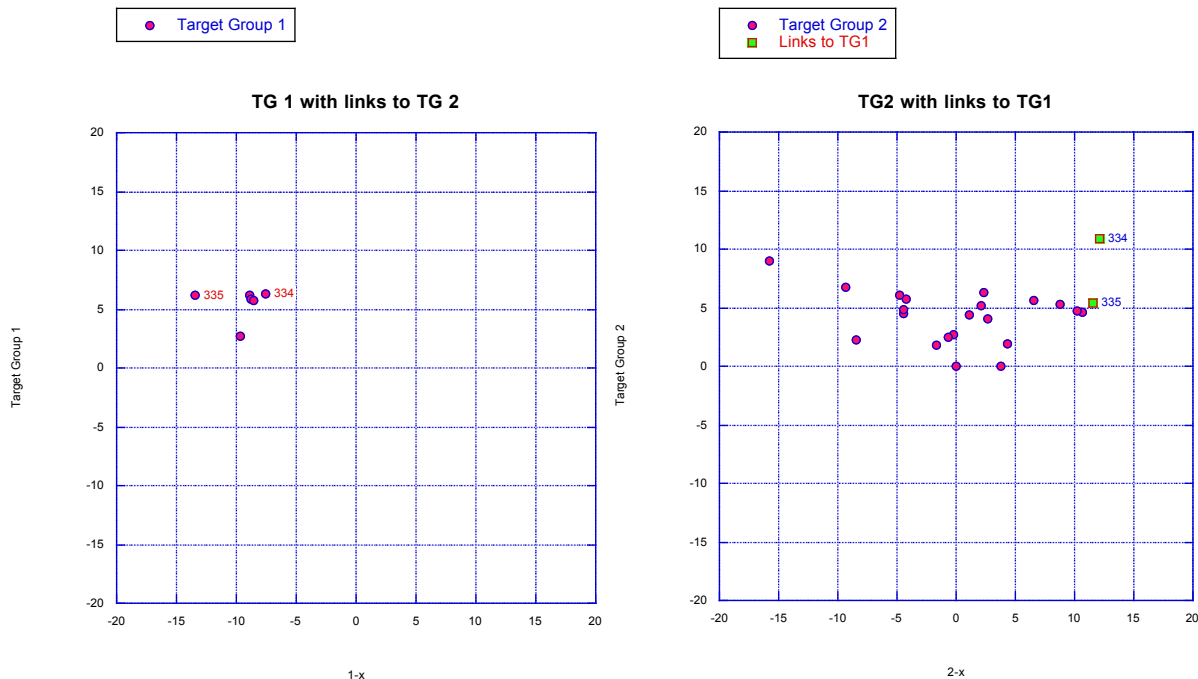
A. Programs Used

- i. We used the program Kaleidograph to obtain maps of the plants from each target group. This program was convenient and can produce figures with a transparent background, which eases the process of linking maps together. We then used Microsoft PowerPoint to determine the degree of rotation needed to make the target groups align correctly.

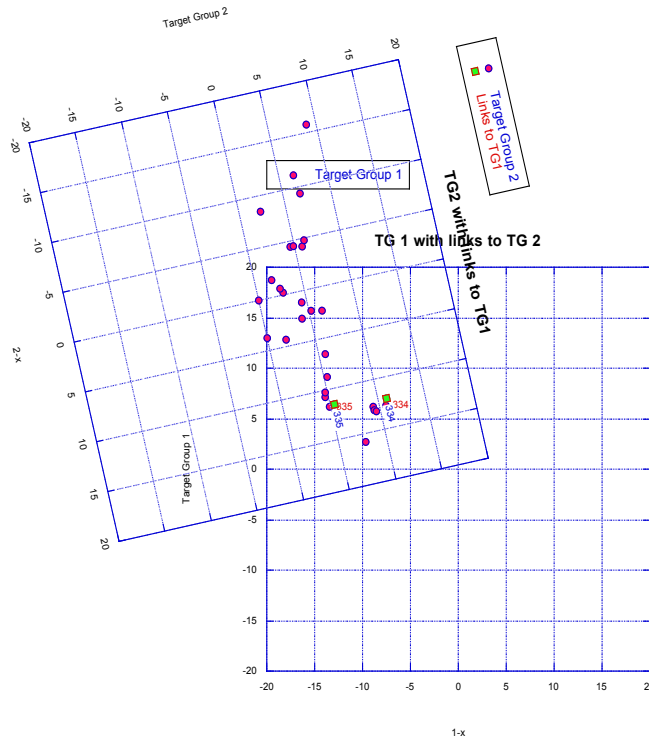
B. Steps for Creating a Map

****The following steps are for target groups 1 and 2****

- i. In Kaleidograph, create columns for;
 1. Target group 1-x
 2. Target group 1-y
 3. Target group 1 labels
 4. Target group 2-x
 5. Target group 2-y
 6. Target group 2 labels
 7. Target group 2 links-x (See Step **1-B-ii**)
 8. Target group 2 links-y (See Step **1-B-ii**)
 9. Target group 2 links labels
- ii. In one plot, graph columns 1 and 2. This is the plot for **Target Group 1 (TG1)**.
- iii. In another plot, graph columns 4, 5, 7, and 8. This is the plot for **Target Group 2 (TG2)**, and includes links to TG1.
- iv. Adjust x-axis and y-axis of both graphs so they are equal lengths both within and between the graphs (e.g., 20 m on each side). It is recommended to make (0,0) the center of the image on the graph being rotated. For example, "TG 2 with links to TG 1" is being rotated to align points 334 and 335 with the same points on "TG 1 with links to TG 2".



- v. Copy **TG1** plot and **TG2** plot and place in Microsoft PowerPoint. Using the rotation tools in PowerPoint, rotate **TG2** so that the objects in common to both maps align. Note the degree of rotation value, and use this in the equations below to determine the new x and y values.



C. Equations

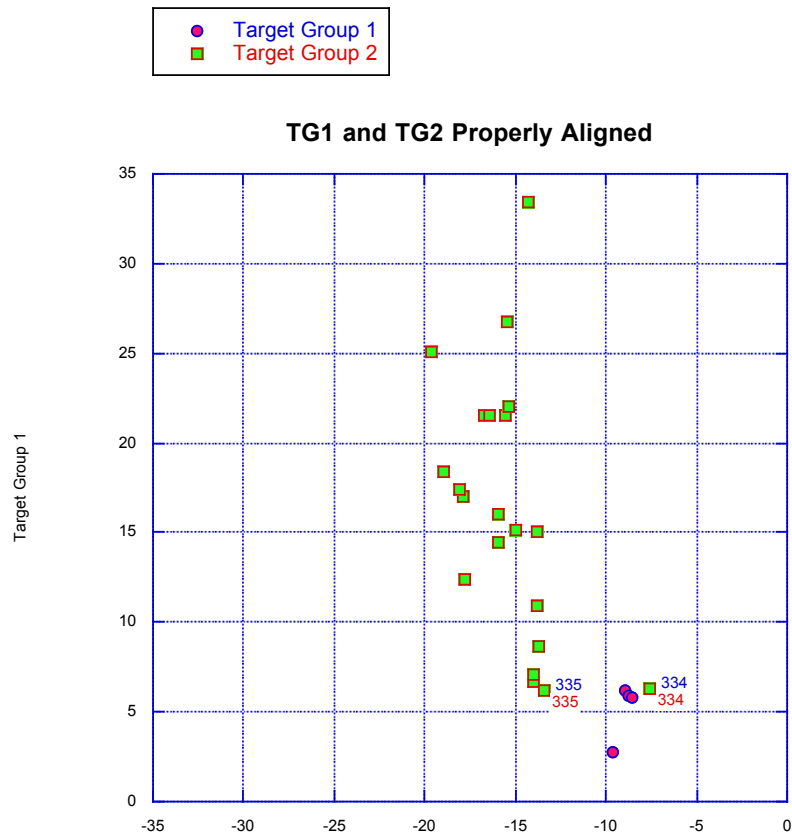
$$p'x = (\cos(\theta) \cdot (px - ox)) - (\sin(\theta) \cdot (py - oy)) + ox$$

$$p'y = (\sin(\theta) \cdot (px - ox)) + (\cos(\theta) \cdot (py - oy)) + oy$$

- i. (px, py) = the point(s) which you are trying to rotate (x - y coordinates from **2-A**).
- ii. (ox, oy) = the point(s) around which you are trying to rotate, i.e., the center of the graph. It is recommended that these points are $(0, 0)$.
- iii. $(p'x, p'y)$ = the new, rotated points.

D. Shifting New Coordinates

- i. Check to make sure that the coordinates for the common points are the same. If they are not, all points in **TG2** will need to be shifted by a constant x and y value. This will be the difference in x and y values for the common points from **TG1** and **TG2**.



E. Repeat

- i. Repeat steps **A** through **D** for all target groups and you will have a population map.

4. Converting data to R for analyses

- A. This step is optional, but recommended for further analyses. Below is the script used to plot the final x and y coordinates of your population.

```
>mydata<-read.csv(file="~/Desktop/coordinates.csv", header = T, sep=",")
>mydata<-na.omit(mydata) #omits errors from Microsoft Excel
>head(mydata)
>mydata.d<-mydata[0:113,1:2]#Isolates x- and y-coordinaetes for var.
daileyae
>mydata.wt<-mydata[114:385,1:2]#Isolates x- and y-coordinates for wild
type
>points1<-mydata.d
>plot(mydata.wt, col="green", xlim=c(-100, 150), ylim=c(-100, 150),
```

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```
main="Reynolds Park Polymorphic Population", xlab="Across the Draw (m)",  
ylab="Up the Draw (m)", pch=1) #Plots wild type individuals with green  
markers, as well as axis labels  
>points(points1, col="red", pch=1) #Attaches var. daileyae individuals to  
the same plot window  
>legend("topright", inset=.05, c("Daileyae"), text.col="red",  
horiz=TRUE, pch=1) #Adds a legend
```