Question 2

a

```
     Whistle        Duration        Center_Freq       Low_Freq       Delta_Freq       Max_Freq         Range_50
 Concave  :300   Min.   :0.0640   Min.   : 2756   Min.   :    0   Min.   : 2734   Min.   :  689.1   Min.   :-4747
 Constant :300   1st Qu.:0.4040   1st Qu.:11025   1st Qu.: 5649   1st Qu.: 9840   1st Qu.: 8785.5   1st Qu.: 3466
 Convex   :300   Median :0.6525   Median :12231   Median : 7512   Median :12392   Median :11369.5   Median : 4536
 Downsweep:300   Mean   :0.7092   Mean   :12307   Mean   : 7617   Mean   :12333   Mean   :11213.1   Mean   : 4690
 Sine     :300   3rd Qu.:0.8790   3rd Qu.:13437   3rd Qu.: 9476   3rd Qu.:14949   3rd Qu.:13436.7   3rd Qu.: 5766
 Upsweep  :300   Max.   :7.2980   Max.   :20327   Max.   :16800   Max.   :22050   Max.   :21533.2   Max.   :11899

   Range_100        Inflections
 Min.   :-8785.6   Min.   :0.000
 1st Qu.:-2584.0   1st Qu.:1.000
 Median : -689.1   Median :1.000
 Mean   :-1094.4   Mean   :1.055
 3rd Qu.:  172.3   3rd Qu.:1.000
 Max.   : 7924.2   Max.   :3.000
```

The above R-output shows the summary of the dataset, and it will be seen that it is required to standardize the numeric variables before performing principal component analysis which makes thye mean = 0 and variance = 1 to satisfy the PCA assumptions. Also, it can be seen that each whistle group have the same number of observed dolphins (300 each)

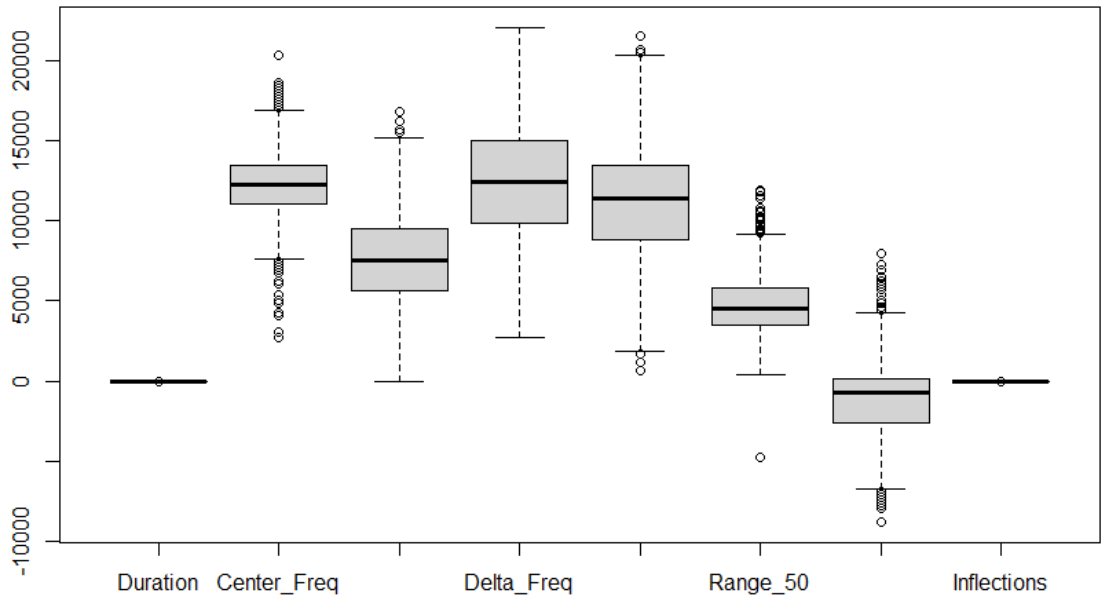


Figure 1: Boxplot of numeric variables

The boxplot above confirms the presence of outliers in the variables of the dataset.

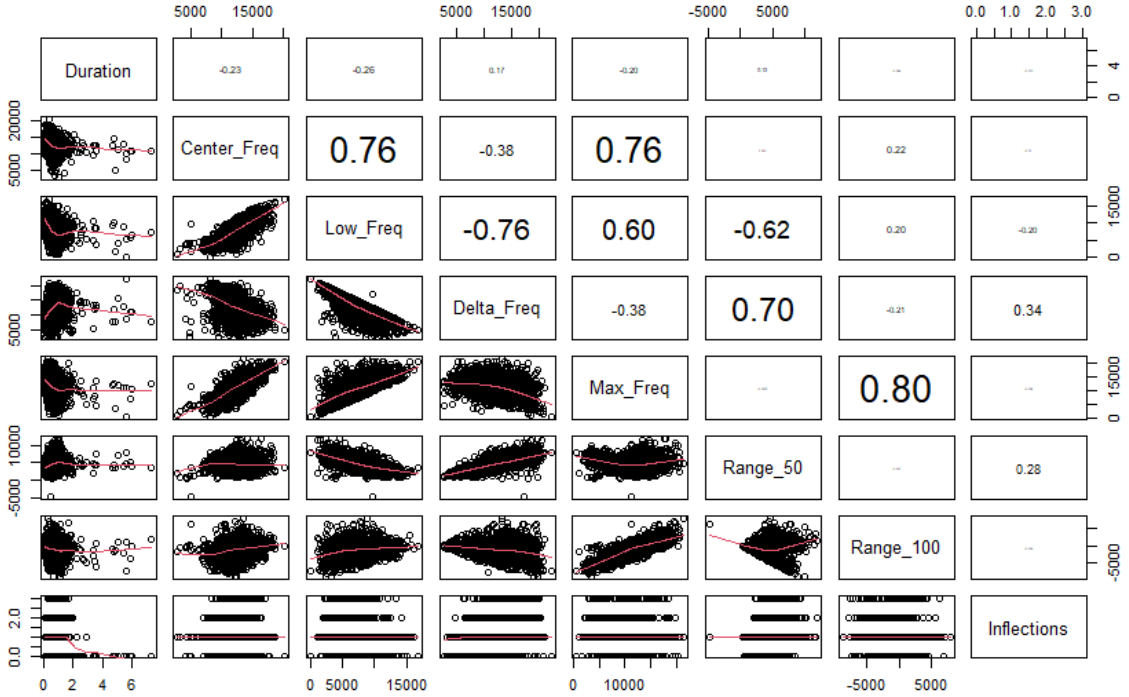


Figure 2: Correlation plot across variables

The pairs plot above shows that there are some frequency variables with a significant high correlation with each other, and some of the pairs with high correlation include; (center_freq V low_freq with 76%), (low_freq V delta_freq with -76%), (center_freq V max_frew with 76%), (max_freq V range_100 with 80%) and (Delta_freq V Range_50 with 70%). And from the plot of variables against each other , it can be seen that majority are linearly related to each other.

b

```
Standard deviations (1, .., p=8):
[1] 1.842 1.315 1.031 0.923 0.859 0.472 0.000 0.000

Rotation (n x k) = (8 x 8):
             PC1    PC2    PC3    PC4    PC5    PC6    PC7    PC8
Duration    -0.180 -0.075  0.670 -0.463 -0.546 -0.016 -0.000 -0.000
Center_Freq  0.405  0.290 -0.197 -0.546  0.050 -0.041 -0.621 -0.158
Low_Freq     0.502 -0.136 -0.167 -0.223 -0.153 -0.325  0.618 -0.376
Delta_Freq  -0.432  0.340 -0.024 -0.056  0.137 -0.822 -0.000 -0.000
Max_Freq     0.433  0.433  0.186  0.027  0.005 -0.055  0.221  0.733
Range_50    -0.282  0.557  0.020 -0.315  0.295  0.448  0.403 -0.245
Range_100    0.277  0.383  0.463  0.548 -0.040 -0.045 -0.146 -0.486
Inflections -0.146  0.363 -0.484  0.182 -0.754  0.102  0.000 -0.000
```

The table above gives the principal component table approximated to 3 decimal places. The result shows the standard deviation of each component. The eigen vectors for each principal components for which each variable is factored by to get its respective component score.

```
Importance of components:
                          PC1   PC2   PC3   PC4   PC5   PC6   PC7   PC8
Standard deviation     1.842 1.315 1.031 0.923 0.859 0.472 0.000 0.000
Proportion of Variance 0.424 0.216 0.133 0.107 0.092 0.028 0.000 0.000
Cumulative Proportion  0.424 0.641 0.773 0.880 0.972 1.000 1.000 1.000
```

The above table shows the importance of each principal component approximated to 3 decimal places. It shows the standard deviation of the data along each component as well as their individual and cumulative contribution to the model. From the table, it can be seen that Component 1 accounts for 42.4% of the model variance, PC2 accounts for 21.6%, PC3 accounts for 13.3%, PC4 accounts for 10.7%, PC5 accounts for 9.2%, PC6 accounts for 2.8%, but PC7 and PC7 do not account for any significant amount of the variability in the model. Therefore, it can be concluded that all the variability of the model can be explained by the Components 1 through Component 6.

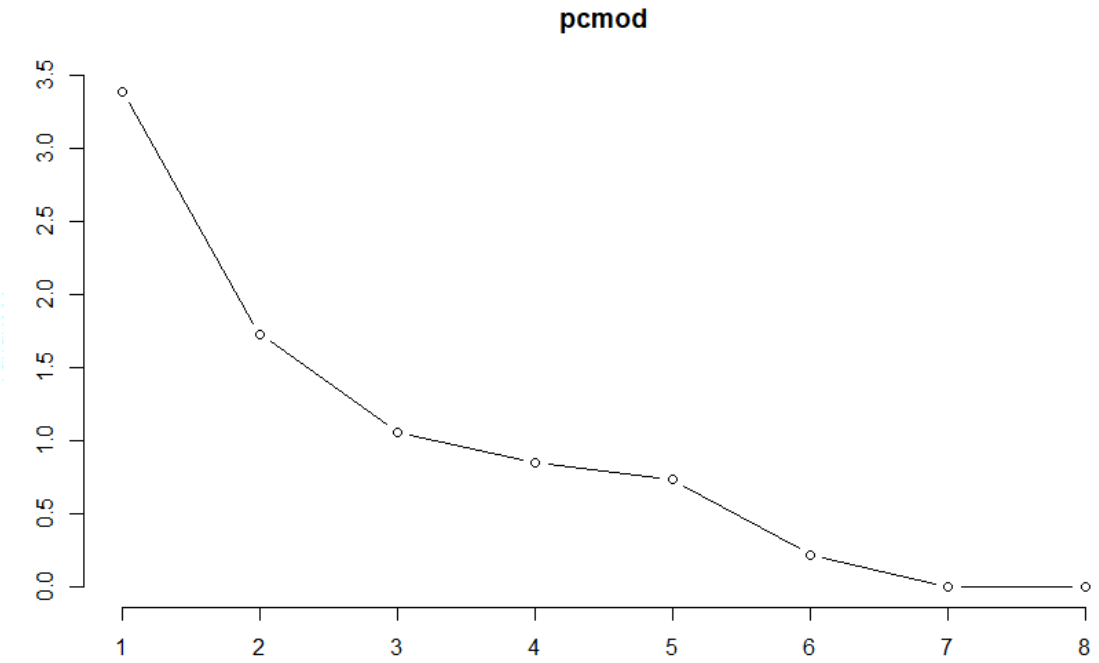
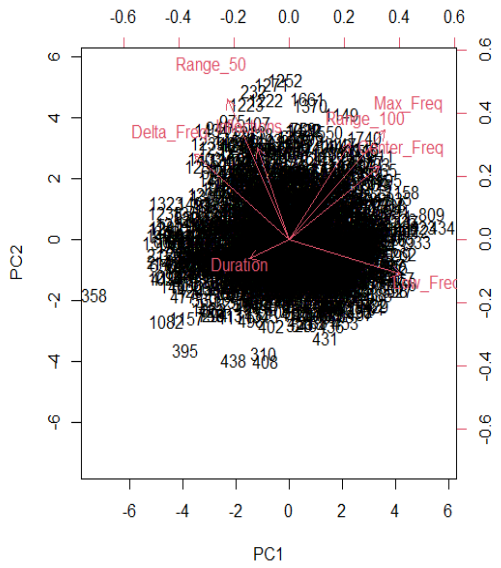


Figure 3: Variance Across each Principal Component

The plot above shows the variance explained across each principal component, and it can be seen that with the addition of each component moving from left to right, the variance decreases and the entire variability is already accounted for at the 6th Component.



Correlation between Principal components and variables

	PC1	PC2
Duration	-0.33	-0.10
Center_Freq	0.75	0.38
Low_Freq	0.92	-0.18
Delta_Freq	-0.80	0.45
Max_Freq	0.80	0.57
Range_50	-0.52	0.73
Range_100	0.51	0.50
Inflections	-0.27	0.48

Figure 4: Biplot of the PC1 vs PC2

The above plot and correlation table helps interpret the principal component across each variable; the principal component 1 and 2 are selected for this analysis as the combination of both of accounts for the highest variability in the model with 64.1% variability accounted for as seen in the table of importance described earlier. The relative length of the vectors (red line) gives the relative variability of the variable. The biplot shows that the maximum and center frequency and the difference between both of them are relatively highly correlated with each other

The plot above can be explained as follows:

- As an observation increases in value on the PC1 axis, its Center, Low, and Maximum Frequency along with its difference between Maximum and Center frequency (Range_100) all increases. At the same time, its Duration, Delta frequency, Inflection and difference between Center and Minimum Frequency (Range_50) all decreases.
- For that same observation, its increase in value along the PC2 axis will cause all variables to increase except for its whistle duration and low frequency which decreases.
- On PC2, much weight is placed on Range_50 variable and the least weight is on the whistle duration, therefore, while on PC1, the most weight is placed on low frequency and the least is on inflection.

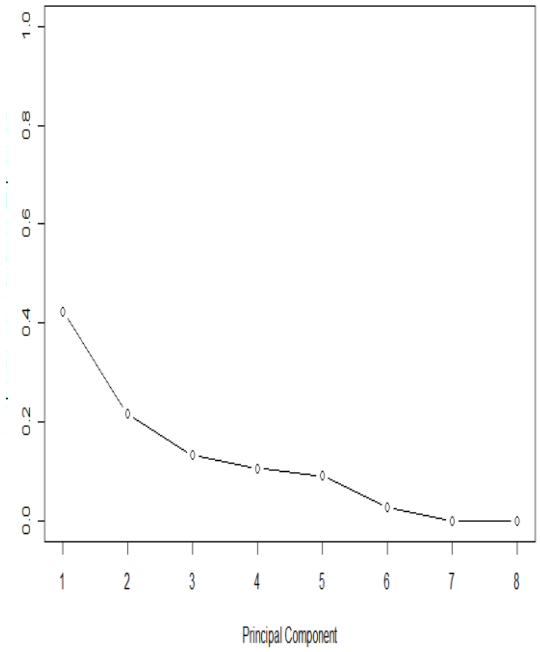


Figure 5: Scree Plot

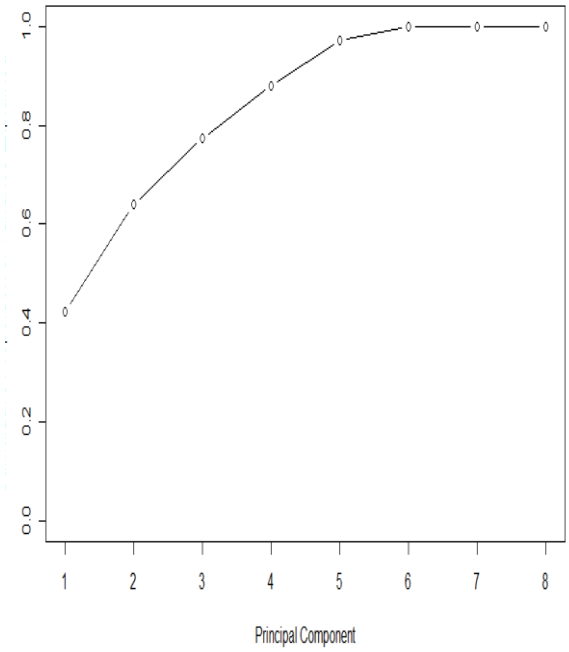


Figure 6: Cumulative PVE plot

The scree and cumulative plots above simply give a representation of the amount of variability captured by each principal component relative to each other. The cumulative PVE plot already shows that the entire model is captured after the 6th loading vector (principal component). And the scree plot shows the level of variability is reduced on addition on a new principal component.

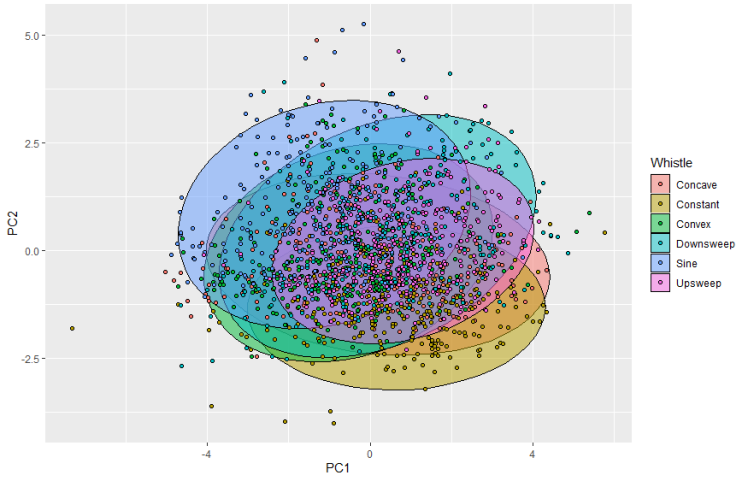


Figure 7: Regions of each group explained by low-dimension representation

The plot above shows the region covered by each group of observation with respect to the variability explained by PCA1 and PCA2. It will be observed that there is still much overlapping between the respective groups which is a result of the 35.9% of the variability unaccounted for from the low-dimension representation. A higher dimension can provide a better structure description of the classification groups thereby explaining more variability in the data.

Question 3

a. Kmeans Cluster

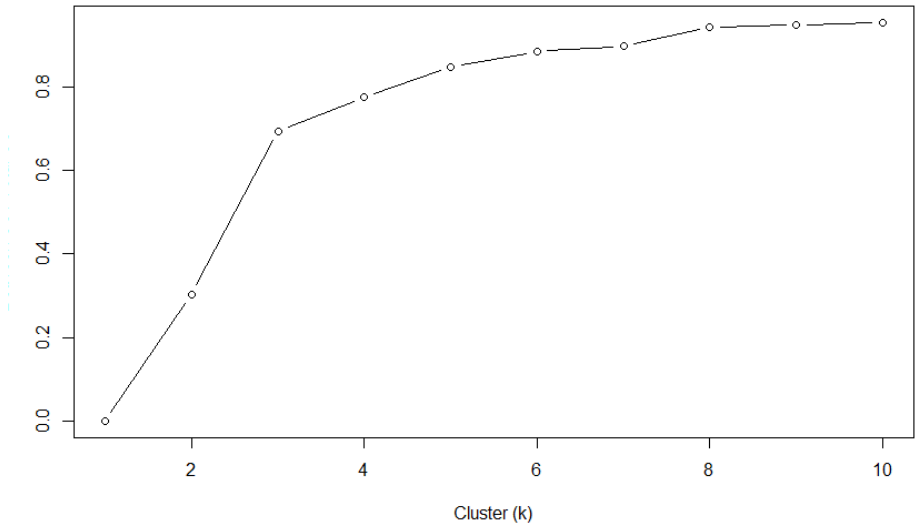


Figure 8: K-Optimization

In the attempt to find the optimal k, the model loops through different values of k, gets the ratio of the between sum of squares to total sum of squares for each model. The result of this ratio is plotted against the number of clusters. The shoulder/kink of the plot is assumed to be the optimal k. The value of the optimal k is 3.

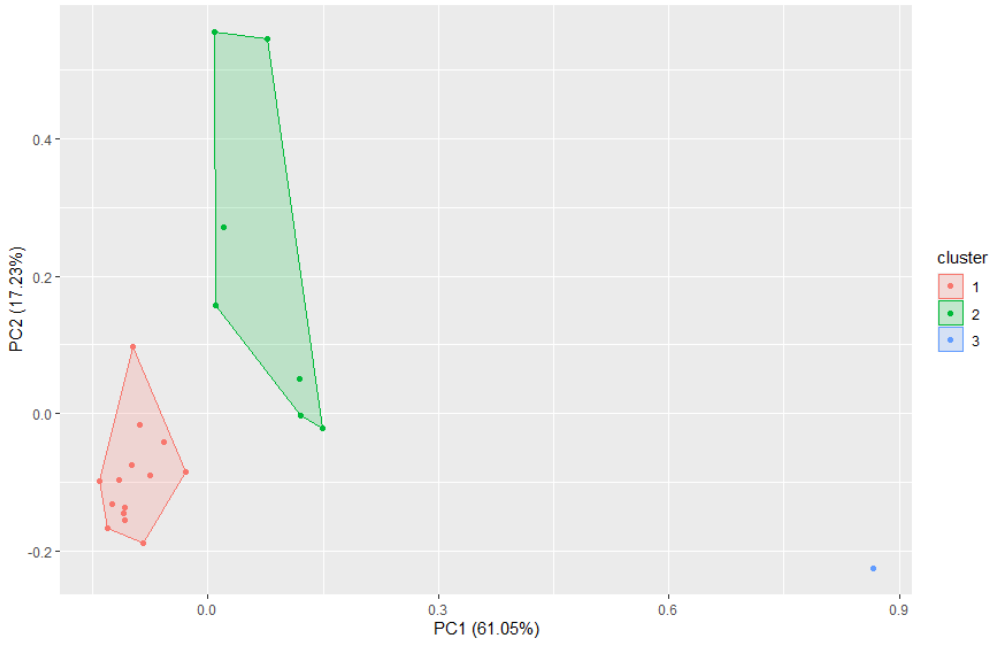
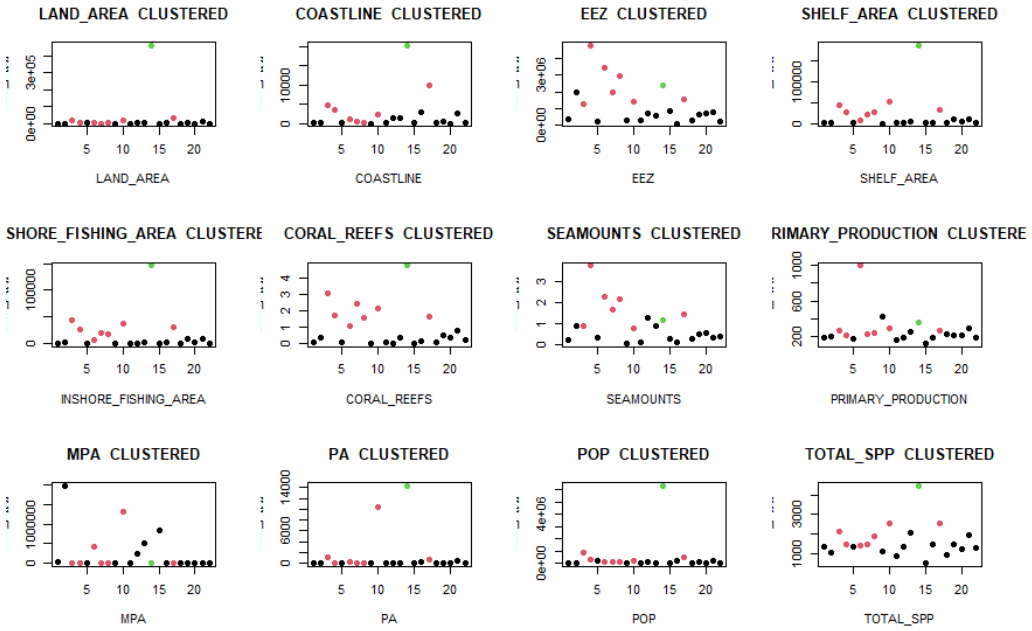


Figure 9: Cluster Plot

The cluster plot above shows the 3 clusters formed by the model from the data, and it can be said that there is a significant distinction between these three clusters. And there is no overlapping between

the clusters; with the PCA component plotted with collectively accounting for over 75% of the variability involved.



The above scatter plot simply shows the result of using the Kmeans cluster model to group the observations of the different variables.

	PICT	prediction	actual
1	American Samoa	1	Polynesia
2	Cook Islands	1	Polynesia
3	Fiji	2	Melanesia
4	French Polynesia	2	Polynesia
5	Guam	1	Micronesia
6	Kiribati	2	Micronesia
7	Marshall Islands	2	Micronesia
8	Micronesia (FSM)	2	Micronesia
9	Nauru	1	Micronesia
10	New Caledonia	2	Melanesia
11	Niue	1	Polynesia
12	Northern Mariana Islands	1	Micronesia
13	Palau	1	Micronesia
14	Papua New Guinea	3	Melanesia
15	Pitcairn	1	Polynesia
16	Samoa	1	Polynesia
17	Solomon Islands	2	Melanesia
18	Tokelau	1	Polynesia
19	Tonga	1	Polynesia
20	Tuvalu	1	Polynesia
21	Vanuatu	1	Melanesia
22	Wallis and Futuna	1	Polynesia

	1	2	3
Melanesia	1	3	1
Micronesia	4	3	0
Polynesia	9	1	0

The above output compares the cluster output from the kmeans method to the actual output. It would be noticed that the method performed better in clustering the region “Polynesia” into cluster 1 and

was not so accurate in clustering the other regions ("Micronesia" and "Melanesia"). This could imply that the model does not account for some variabilities in the data.

b. Hierarchical Cluster

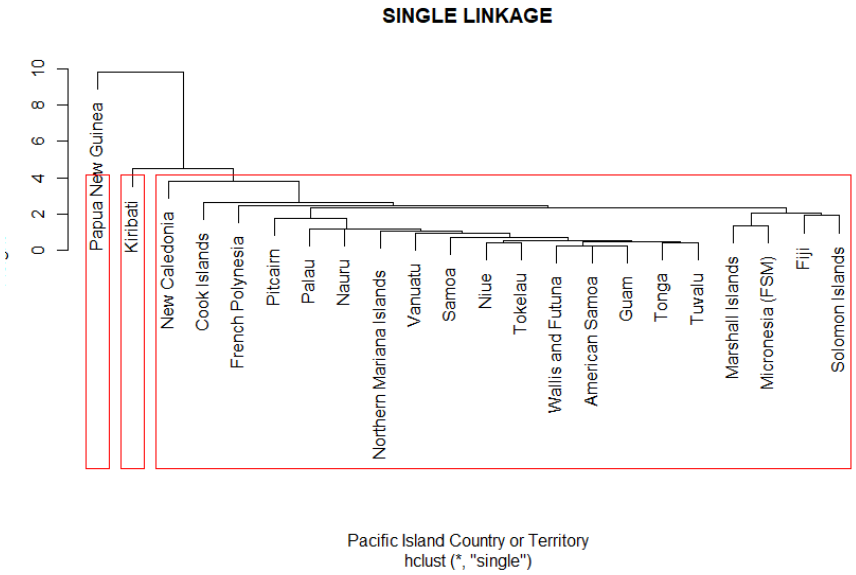


Figure 10: SINGLE LINKAGE DENDROGRAM

The dendrogram above is created using the Single Linkage Method, and it will be observed that this method of cluster formation minimises the distance between unit groups to form a cluster. With 3 cluster groups selected to classify the data, 2 clusters consisting of a unit observation each and the third cluster consisting of the remaining 20 observations were formed. This signifies that the 20 observations in the third cluster have the smallest distance among each unit compared to the other 2 clusters that are significantly farther from the cluster.

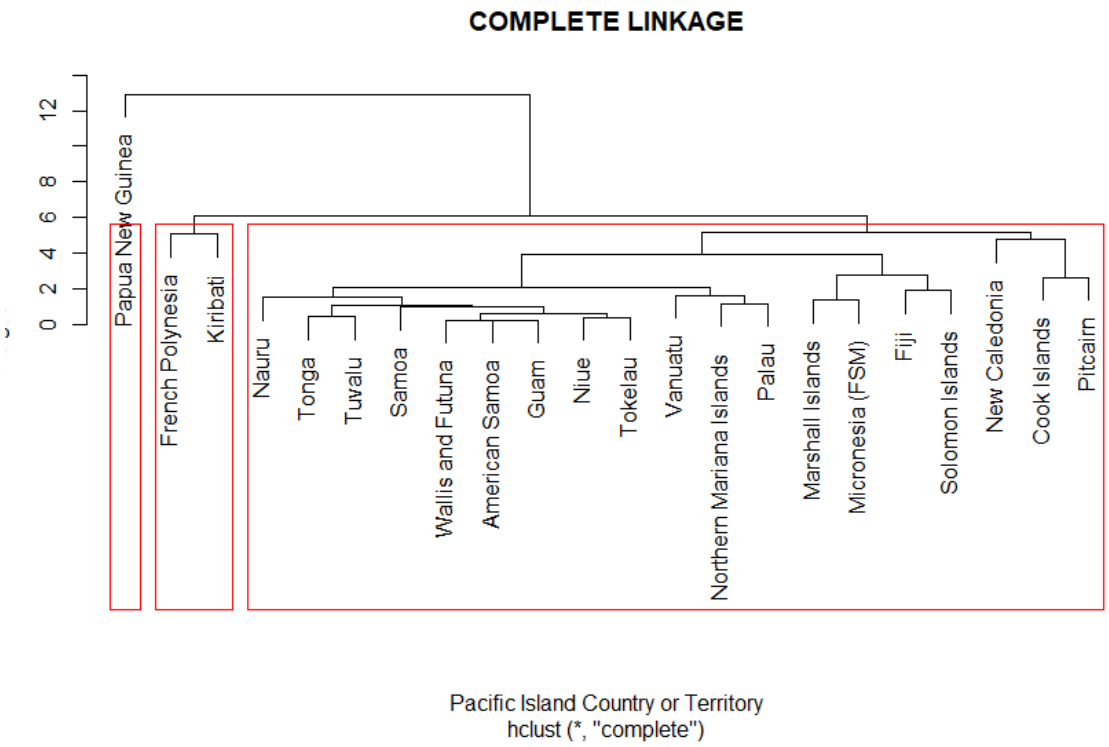


Figure 11: COMPLETE LINKAGE DENDOGRAM

The complete linkage dendrogram is formed by maximizing the distance between points when computing new distance points. It can be seen that the clusters are tighter than the single linkage method. From the above figure, it can be seen that clusters are mostly formed in pairs and this indicates that those pairs are at the farthest distance from each other, and this helps to create a balance in the dendrogram.