

For the purpose of this project, we have studied a network of social interactions between 62 dolphins living in the Doubtful Sound off the coast of New Zealand. In this case, the nodes are individual dolphins and the links represent that the two connected dolphins have been observed in the same group. This network is interesting because dolphins are very social animals who will form alliances and have long-term individually specific relationships much like humans.

Previous work has been done on a similar network in which the researchers investigated the relationship between early social network formation in bottlenose dolphins and juvenile survival rate. Since number of connections and cohesiveness of groups have been linked to lower rates of morbidity and mortality in humans, they were interested in seeing if a similar correlation could be involved in dolphins as they are also long-lived socially complex mammals. Their main result was that early social interactions did affect the probability that a calf would survive to adulthood, however the nature and quality of social bonds were more predictive of survival than just the number. They also found that this trend was much more pronounced in male dolphins than female.

We examined the social network of dolphins in Doubtful Sound and compared our results to those of the attached paper.

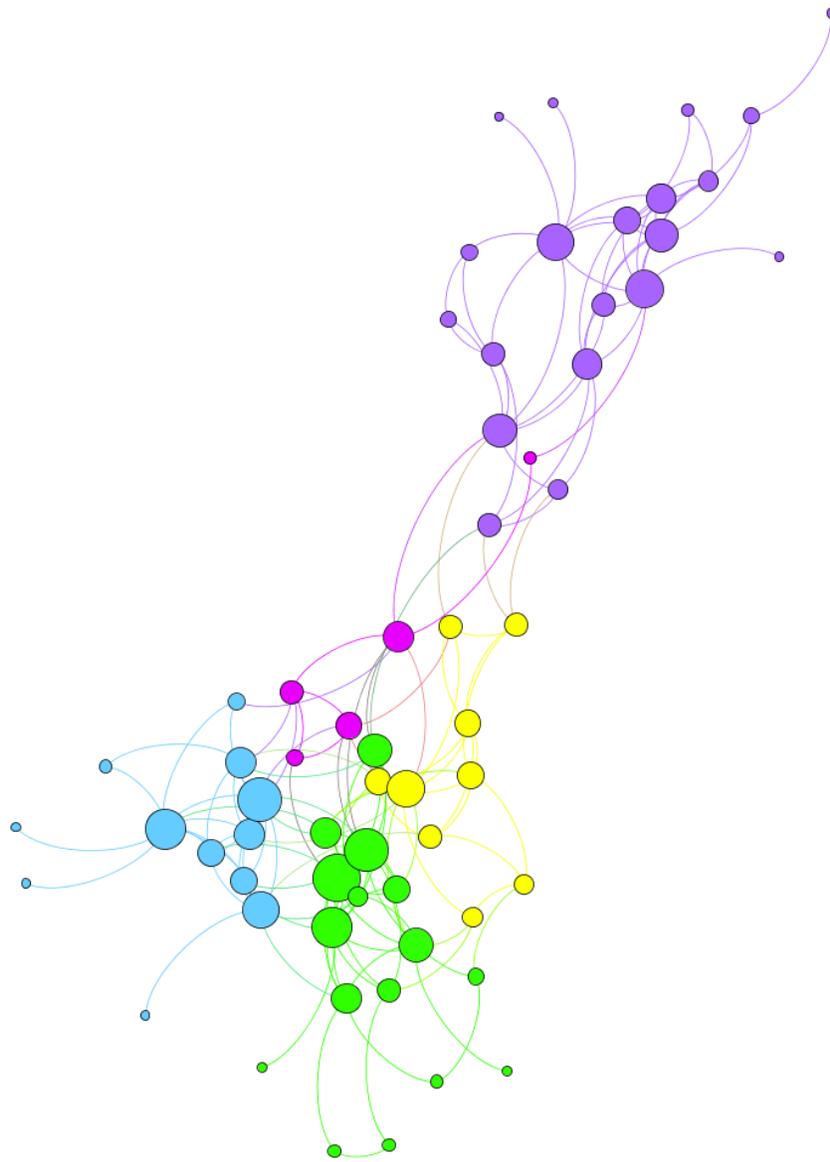
METHODS AND ANALYSIS

There are 159 links between the 62 observed dolphins living in Doubtful Sound. After calculating the average degree and clustering coefficient of the network, we compared it to both random graph and small world networks. The results are presented in the table below.

NETWORK	NODES	LINKS	p	<k>	kex	<C>
Dolphins Social Network	62	159	-	5.129	-	0.303
Small World	62	155	0.5	5.919	3	0.36
Random Graph	62	167	0.084	5.113	-	0.114

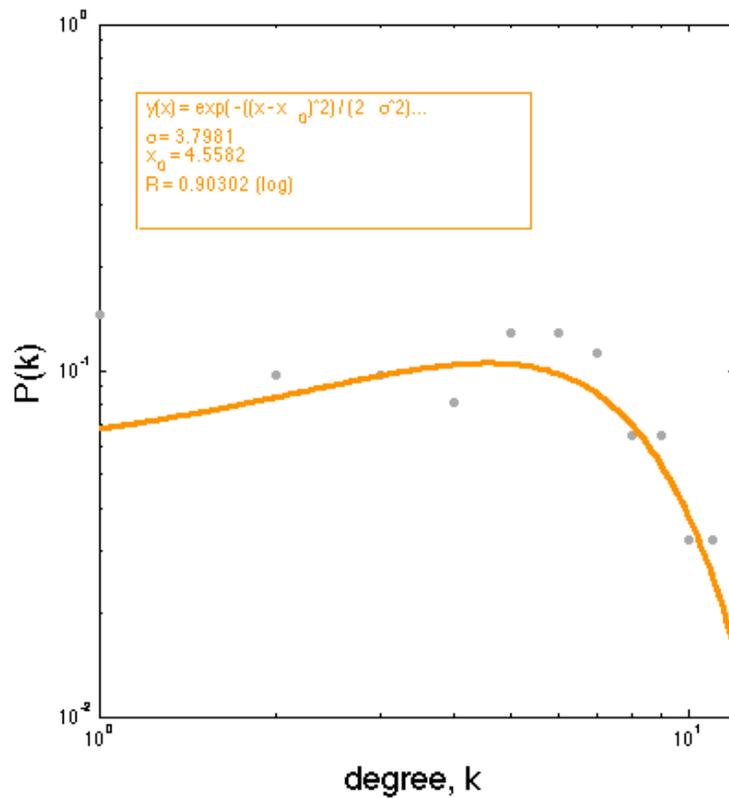
By altering the parameters for the small world and random graph networks, we were able to obtain networks of similar size. We find that the dolphin network is most like the small world network due to the likelihood of cliques forming within the community.

After obtaining the Doubtful Sound dolphin data, we imported it into Gephi to create the following visualization.



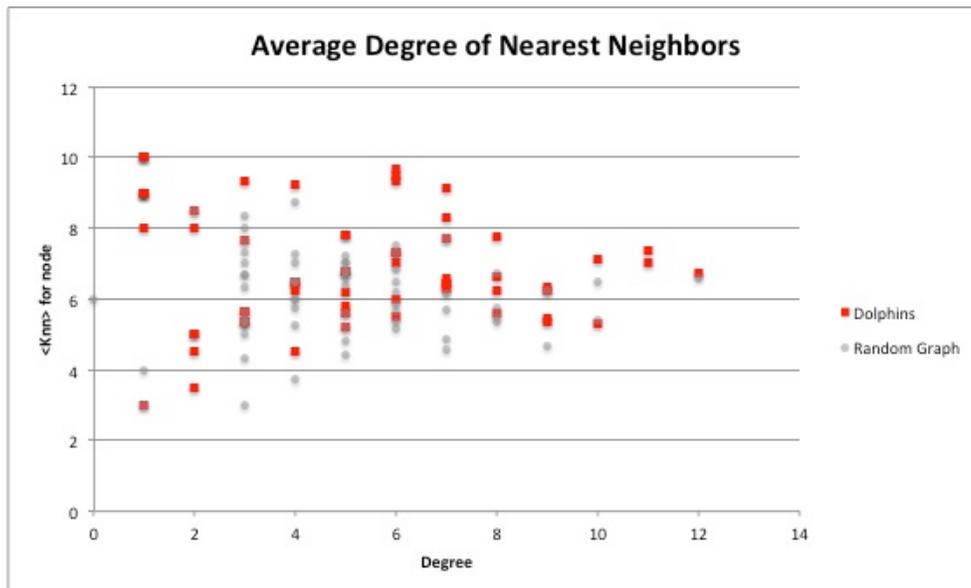
The two attributes that interested us in the network as a whole were the degrees of individual dolphins and the communities to which they belong. Here, the circles represent dolphins and the links represent an observation of them interacting at some time during the trial period. Larger circles are dolphins of higher degree, meaning they have more dolphins with which they interact. Five communities of dolphins are observed, indicated by the five colors, by analysis of the modularity coefficient.

Further exploring the degree of individual dolphins, we found the probability distribution for the likelihood of observing a dolphin of a certain degree.



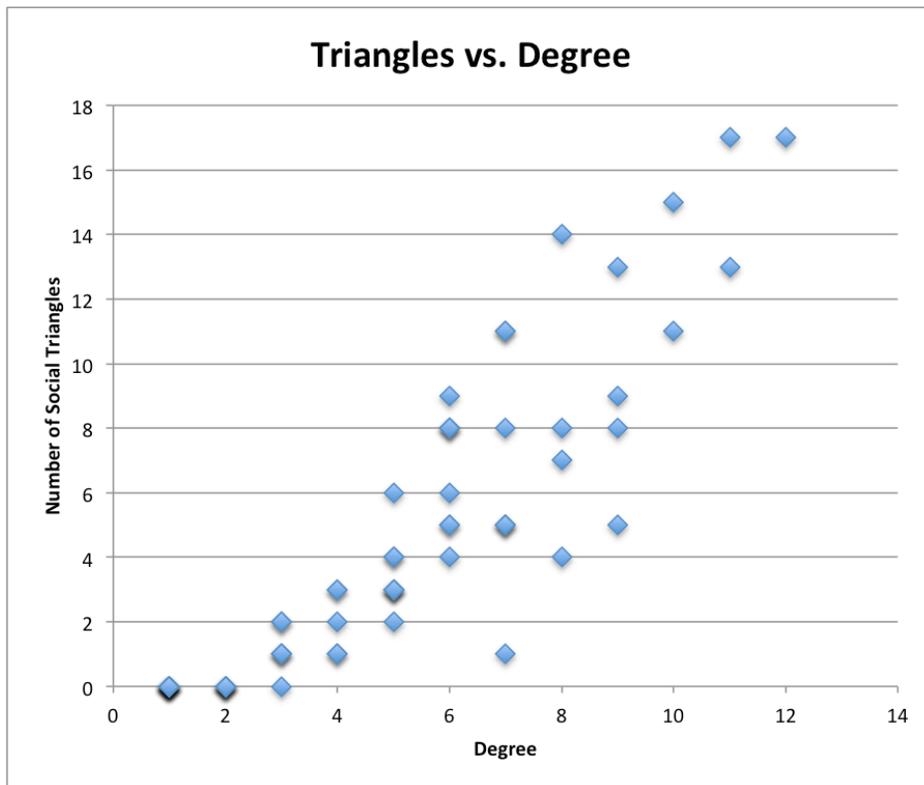
The degree distribution for these dolphins is fit relatively well by a Gaussian distribution. We note that it is unlikely for dolphins of a high degree to exist.

In order to confirm that the dolphin social network is similar to a small world network, we explored the average degree of each dolphin's nearest neighbors. The results are shown in the following graph.



The graph shows no assortativity or disassortativity with regard to connections that dolphins make. Human social networks are very assortative, meaning popular people are friends with popular people. In terms of the network, this means that nodes of a high degree are connected to other nodes of a high degree. In the case of the dolphin social network, no such correlation is observed, following pattern more similar to the random graph network of similar size.

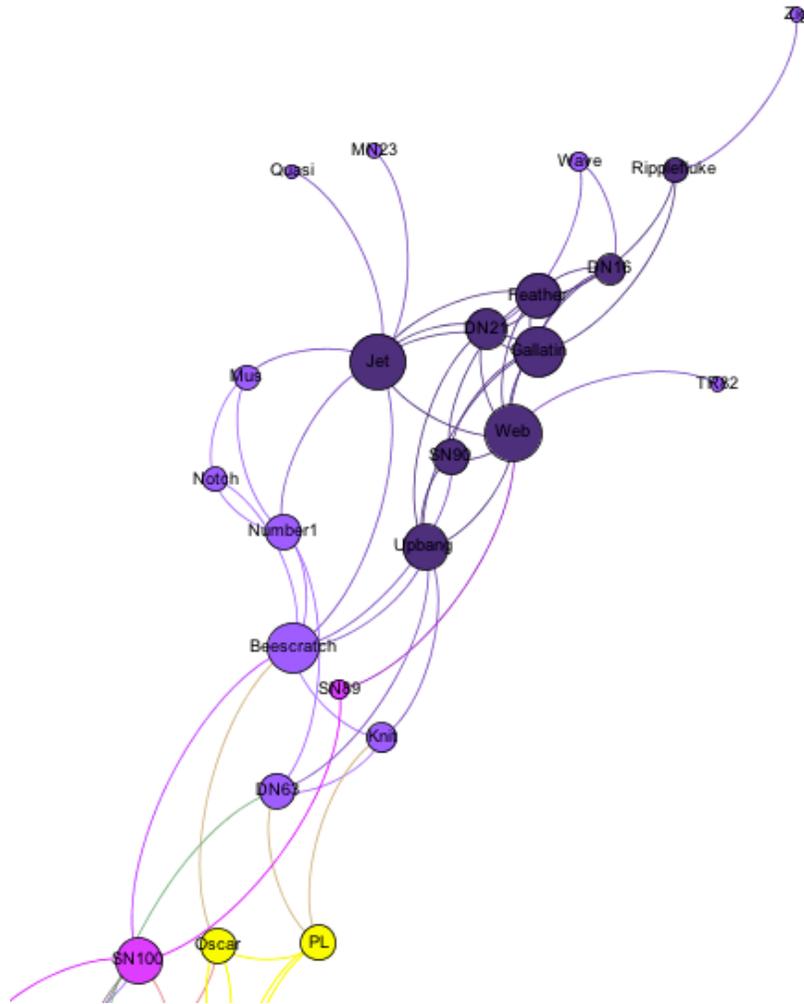
Our visualization also shows that dolphins form communities within the network. We thus analyzed the triangles that dolphins form.



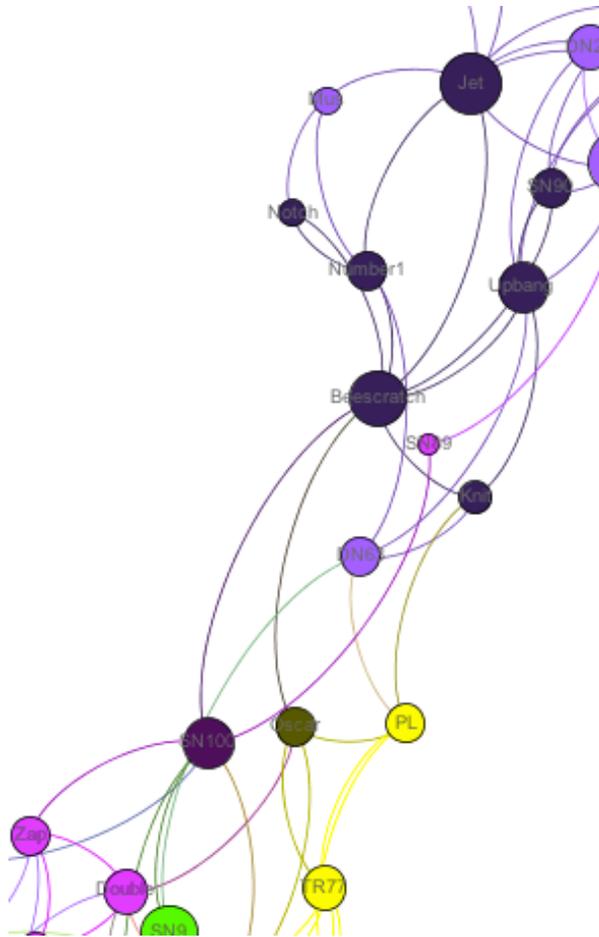
While it is expected that the number of triangles will increase with degree, we noticed that there are cases where dolphins of a relatively high degree did not have a correspondingly high number of triangles. Dolphins of this latter type were likely to have friends in more than one community.

To explore this, we looked at two dolphins, Gallatin and Beescratch, both of degree 8. Gallatin's friends are very connected, as he is a part of 14 triangles. Beescratch, on the contrary, did not have quite as connected friends.

Zooming in on Gallatin, we see that he is part of the community pictured in purple in our network visualization.



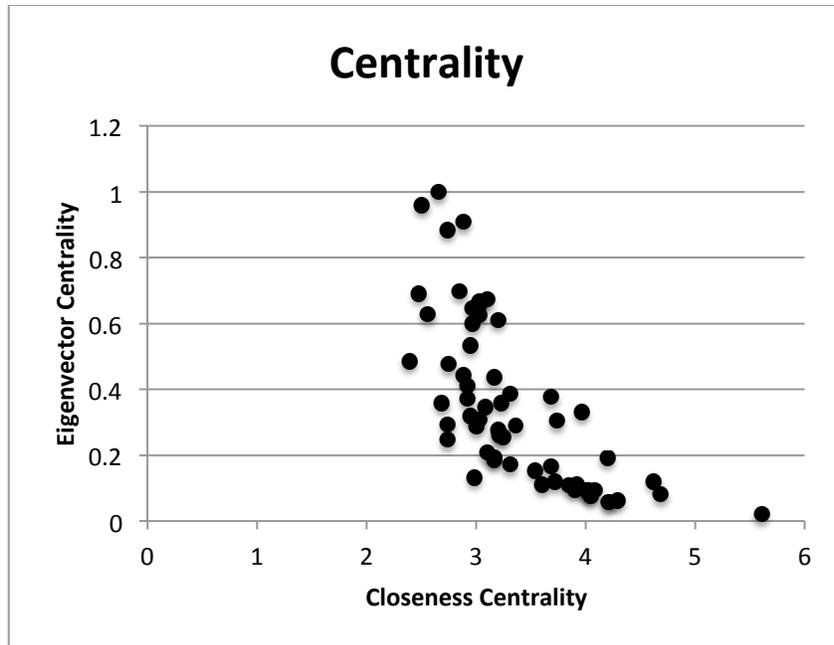
In the above figure, we have zoomed in on Gallatin and his friends. We see that all of Gallatin's connections are in the same purple community of which he belongs. The same cannot be said for Beescratch.



Beescratch's connections span three communities and are indicated by the darkened nodes in the figure above. Since Beescratch has several friends outside of his own community, the likelihood of having a significant number of triangles is small.

Connection to Other Works

In "Early Social Networks Predict Survival in Wild Bottlenose Dolphins," Margaret Stanton and Janet Mann explore the idea that as social mammals, a dolphin's interactions with other dolphins are key to its survival. They further conclude that it is the quality, not quantity, of these interactions that are important.



We analyzed the centrality of the 62 dolphins in Doubtful Sound. While we did not have data regarding the mortality rate of the observed dolphins, we did see similar patterns as observed by Stanton and Mann. They note that dolphins with a high eigenvector centrality are more likely to survive because they interact with dolphins who are “more important” or more central to the group as a whole. From our analysis, we see in the above figure that dolphins with a high eigenvector centrality have a lower closeness centrality. These dolphins are more likely to survive, explaining why the majority of them are within the same range. We can further conclude that dolphins outside this cluster, those with high closeness but low eigenvector centralities, are likely female dolphins, namely mothers. These dolphins influence the social interactions of their offspring, however, they aren’t involved in many relationships with other important dolphins.

Conclusions and Future Work

Through our analysis of the Doubtful Sound dolphin social network, we found that dolphins in cliques tend to fall into one of two categories. The first is exemplified by the dolphin named Gallatin. He is connected to 8 other dolphins, every one of which is within his community; so although he only has 8 neighbors, he is a part of 14 triangles. The second category is demonstrated by Beescratch. Beescratch is also connected to 8 other dolphins, but his friends fall in 3 separate communities; he is therefore only a part of 4 triangles and is somewhat of a “social butterfly.” Based on our degree distribution, we further conclude that while high degree dolphins do occur, they are very unlikely as dolphins tend to remain within their small communities.

An interesting direction that future analysis related to this network could take would be to investigate how juvenile social interactions affect female dolphins, because while they have not been strongly linked to survival, it could be correlated to reproductive success or some other attribute specific to females. Alternatively, the mother’s role in a juvenile’s social interactions

could be further investigated as this study controlled for maternal identity and maternal social choices would clearly have an effect on a calf's development pre-weaning.