Sanak Intertidal Food Web Dataset Analysis

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***Abstract*—This report aims to analyse the Sanak Intertidal Food Web, particularly by looking at humans as a key aspect of the analysis. This paper involved executing two algorithms on the dataset – Girvan-Newman community detection and Eigenvector centrality. The Girvan-Newman algorithm was used to discover different interconnected communities, and the Eigenvector algorithm was used to distinguish the nodes that were deemed as more 'central' to the network. Humans were found to be a very important species in the ecosystem, as the Eigenvector score for this node was found to be the 3rd highest. Additionally, humans were found to play the role of highly omnivorous consumers as they fed on both animals and plants in the ecosystem, demonstrating their interactions with the various species habituating the ecosystem. When humans were removed from the network, various properties in the network were affected, including resulting in a higher average path length (representing less energy being transferred), and other species becoming increasingly important in the network.**

I. Introduction

The Sanak Intertidal Food Web shows the species of an ecosystem (represented as nodes in the network), and the trophic links between them (represented as edges in the network). This shows whether a species consumes or is consumed by another. This illustrates how the energy is transferred between different species. This report will analyse the dataset by having executed two algorithms – Girvan-Newman community detection and Eigenvector centrality.

The aim is to gather information about the network, such as shortest path lengths, that can provide details on implications in the real-world. For example, nodes that are deemed as 'important' (through the Eigenvector centrality algorithm) may be deleted to represent the extinction or migration of a species. This may also affect the shortest path lengths, which will then affect energy transfer between species. This can help to provide the repercussions such events may have in real-life – with these events inluding a key or central species suddenly disappearing from the ecosystem. This would be the equivalent of a species becoming completely extinct, and to a lesser extent, it would provide insights into the consequences of the population of a species drastically decreasing.

The problem currently, in terms of food webs and ecosystems is that most of the studies focus on the human impacts on an eosystem, and relations between non-human organisms. However, it is also important to understand the roles that humans play in an ecosystem, and the interactions they have with other species, and how essential they are as a species themselves within the sustainability of the ecosystem.

It is very common in many scientific studies to find how species (other than humans) interact with each other and how this forms a predator-prey relationship hierarchy, with energy being transferred at each trophic level (the number of steps the organism at that level is away from the start of the food chain). The problem is that, in many cases, humans are taken out of the equation when it comes to ecosystems and are not included in the hierarchy (since we, as humans, do not live directly in a natural ecosystem). This report will aim to understand the roles humans play in the ecosystem by looking at not just the impact that they have on the ecosystem, but also how they are integrated in it through their interactions with other species in the ecosytem.

It will also be helpful to identify the important communities within an ecosystem – that is, the species within the ecosystem that interact with each other more strongly (have denser links between them).

In this paper, we also discuss and analyse the dataset statistics, taken from a network analysis and visualisation tool known as Gephi. Appropriate functions were applied to investigate the impacts of humans and other important species in the ecosystem, such as *Detritus Complex*. These statistics are analysed in detail in section 5 – *Results*, with conclusions based on these being drawn in section 6 – *Conclusions*.

II. Related work

There are many scientific journals that worked with a dataset involving food webs and ecosystems, although some of their primary goals differ. However, certain papers, such as the one titled 'Human ecodynamics: A perspective for the study of long-term change in socioecological systems' investigate the effects of humans on social-ecological relationships [1]. This is a similar field as the investigation was primarily focussed on the role of humans on socioecological systems, and any effects they may have on an ecosystem.

One of the elements that the study looked at was the evolution that takes place in an ecosystem to explain and justify the effects and changes that took place – since an ecosystem is composed of several different organisms, there are a large amount of small biological changes that can occur over a long period of time within organisms, which can affect the population of each of the species. Along with the changing characteristics of the species, there are also ever-changing conditions such as weather and resource availability – which can all affect the ecosystem.

Another research study investigated how food web structures and ecosystems changed due to environmental warming. Although the factor that was being explored (temperature rise) was different, what was being investigated was an ecosystem and the organisms within the community. This also has implications for many other ecosystems, as weather conditions can affect whole communities and therefore, not just the one. It was found that the increasing temperatures reduce the amount of top predators and herbivores in a disproportionate manner, which results in communities being dominated by autotrophs and bacterivores. This can greatly affect the equilibrium within the ecosystem, as the lower trophic organisms in the community have their populations naturally increased due to the decreased number of higher trophic level organisms, leading to a decline in diversity [2].

This can have huge implications on ecosystems that have changing environments and temperatures, especially with global warming becoming more prevalent as the years go on, which can greatly affect the sustainability of communities of organisms that rely on the interactions with each other and the surrounding environment.

Another study looked at the interaction strength between different organisms in a marine food web, and primarily focussed on the effects on this ecosystem that were caused as a result of overfishing by humans. This was similar as it was investigating the impact that humans had on the food web, and the data that was being looked at was also very similar (a marine food web) [3].

It was found that the co-occurrence of 'strong' interactions between two consecutive levels of food chains (two trophic levels) occurred less frequently than expected by chance. Even when these interactions did occur, they were accompanied by strong omnivores. The combination of the interaction strength was found to lessen the likelihood of trophic cascades (which are strong indirect interactions that result from a trophic level being supressed), after the top predators in the community were overfished. However, it was also discovered that humans partaking in the act of fishing selectively removed the predators that were overrepresented in the strong interactions.

There was also a research study that investigated the roles of human hunter-gatherers in North Pacific marine food webs, and specifically looked at two ecosystems in Alaska, one of which included the Sanak Intertidal food web (which is the same dataset that is being analysed in this paper) [4].

It was found that the humans involved in the community played important and distinct roles as highly omnivorous consumers, and were closely connected to other species. Although they consumed plenty of other organisms in the community, it did not appear that the introduction and presence of these humans had any long-term extinction effects on the species in the community. In a way, this meant that the arrival of humans in this ecosystem helped the ecosystem to thrive and maintain itself, as humans consuming a large portion of the ecosystem's species allowed their populations to be kept controlled, which otherwise would have increased due to a predator lowering these numbers. Not only did this increase diversity through the inclusion of a new species (*Homo sapiens*), but also did it enable the longetivity of it. This was helpful into gaining an insight on why humans were so important in this food web – so this begs the question – what changes (if any) would occur in this ecosystem if humans were to be taken out of the equation?

Another study investigated trophic cascades and the effects of predation risk on food web interactions. Trophic cascades are powerful indirect interactions that can control entire ecosystems, which can result from a trophic level in a food web being suppressed. This was in a similar field to the problem we wished to investigate as the 'predators' in this dataset are the equivalent to humans acting as omnivores in the Sanak Intertidal food web [5].

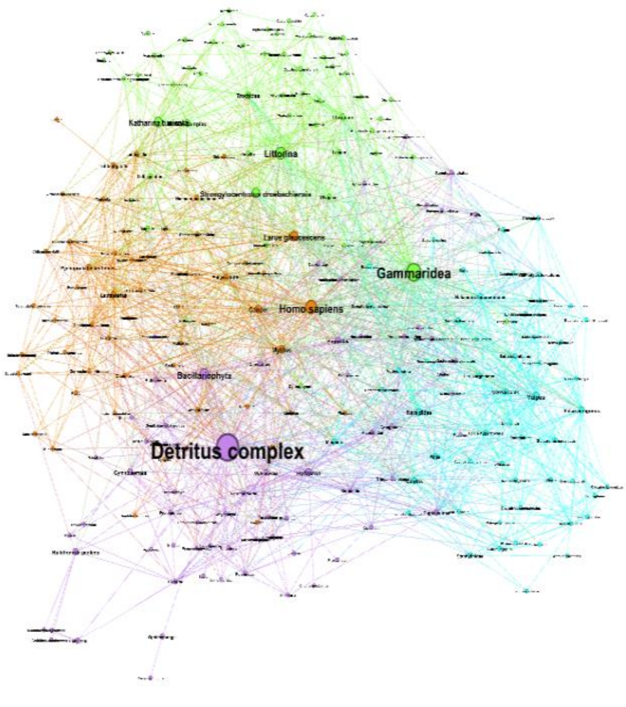
This study found that direct population effects can cause trophic cascading – including, but not limited to – predators preying on herbivores in the community, thereby decreasing the abundance of herbivores in the ecosystem. Cascading can also be caused by indirect behavioural-level effects, such as when herbivores (prey) shift their bevhaviours due to an increased risk of predation.

III. DATASET

A food web is similar to food chain, where a number of species are connected via links – this indicates whether they are consumed by other species, usually shown by an arrow (illustrating the energy flow from the species being consumed). A food web however, is larger, combining multiple food chains into one, showing the interconnections between these different food chains. Each link represents energy tranfer from one species to another, with the amount of energy tranferred decreasing at each trophic level, as at each level, the organism uses some of the energy that it gains for necessary natural processes.

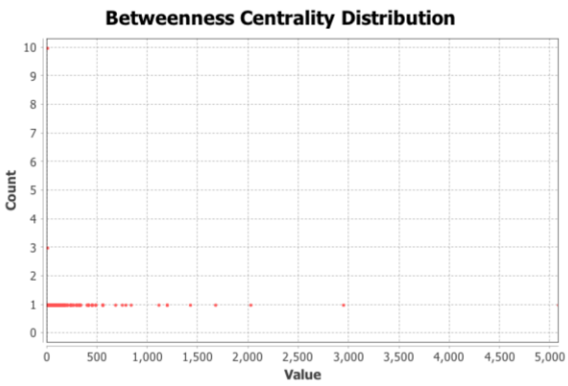
The dataset was retrieved from nature.com, which was redirected to from icon.colorado.edu. As mentioned earlier in the report, it investigates the Sanak Intertidal Food Web, which is an ecosystem located in Alaska. It mainly includes species that are of a marine origin, while including humans as a part of the ecosystem as they are very much involved in it through interactions with species in the form of fishing and hunting.

Although humans may not be directly involved in the ecosystem as other species (e.g. by consuming them directly through living in the habitat), they still nevertheless contribute to the sustenance of the ecosysem and play a key role in maintaining population numbers of other species. Without humans to naturally keep these numbers in check, the population of certain species can grow exponentially, which could have a significant impact on the ecosystem.



Upon visualising the network through Gephi and applying the appropriate layout functions, it was immediately seen that humans (labelled as Homo sapiens in the graph) had a key role in the ecosystem as they had a relatively large size (node size), when the species were sized according to betweenness centrality (a function provided in Gephi – the graph is shown below). Betweenness centrality is the measure of centrality based on the shortest paths – and in this case, it demonstrates shortest paths between the species that are consumed by humans, and relations between various other species in the ecosystem.

Since an edge represents a trophic link and whether a species consumes or is consumed by another (undirected or bi-directional graph), the original data was inspected to confirm whether humans consumed all of their neighbours – this was expected and happened to be the case. This means that humans are on the top of each of their food chains, receiving energy via the trophic links through the many species they interact with.



The above graph shows the betweenness centrality values across the nodes in the network. Centrality refers to the importance of a node, and in betweenness centrality, this is calculated through determining the shortest paths between the node that is being investigated and all other nodes. For every pair of vertices, there exists at least one shortest path between the pair, such that the number of edges that needs to be travelled across is minimised.

The highest betweenness centrality value was found to be 5076.9. This belonged to the *Detritus complex*, which was the largest node and also had the highest degree in the network. Detritus is dead organic material that is used as a source of nutrition for many organisms. Detritus is important in the ecosystem due to organisms that feed on it, which are then a part of their own food chains involving more complex organisms, such as *E. jubatus* (Steller sea lion). This was a very high betweenness centrality value (calculated for *Detritus complex*), relative to the other betweenness centralities found for the remaining nodes. Since it has the shortest path (relative to other species) in the network, it is the node in the ecosystem that is most consumed first in each of the food chains that it is involved in.

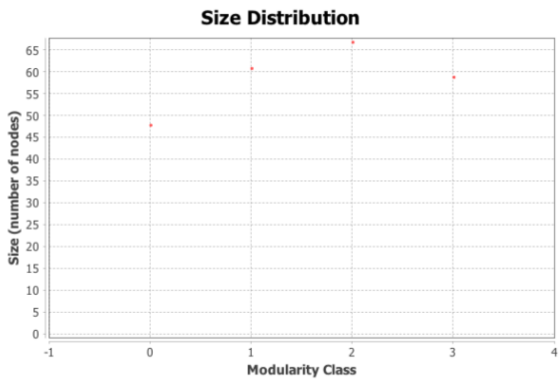
The *Homo sapiens* node size indicates that it has a high betweenness centrality, and the network also shows (in the original data) that it has 70 neighbours – this demonstrates that humans feed on 70 (29.7%) other taxa in the network, or more accurately, have a trophic link to them. They also have the 3rd shortest mean path length, which is defined as the number of links that connects a species to another. This tells us that 94.4% of the taxa were within 2 links of humans.

This alone shows the impact of humans in the ecosystem, as them having a trophic link to 70/235 taxa indicates that they play a key role in maintaining the appropriate numbers of species in the ecosystem. If humans did not have links to the taxa showed in the network, the population of the species that no longer have a link to them will be expected to be higher. This can have a huge effect on the integrity of the network, as a greater population of certain species can lead to a decrease in another, causing an imbalance to the current state of the ecosystem.

It was also found that Homo sapiens were the 6th most omnivorous consumer in the Sanak Intertidal dataset – it was discovered that they fed on various kinds of species, ranging from algae to a genus of flatworms known as *Alaria*, and also to species in higher trophic levels such as *Larus Glaucescens* (Glaucous-winged gull). Humans being high-profile omnivores results in them having a middle-of-the-pack trophic level at 2.98, with the highest level being 3.98 [4].

The network pictured is 'clustered' into 4 modules – this is shown by the four different colours used to colour nodes (species), where each coloured cluster represents a module as calculated by the Modularity class function in Gephi. Networks with a high modularity have more dense connections between the nodes within its identified modules, but sparser connections between nodes that belong to different modules.

The graph below shows the size distribution (modularity) in each module, by illustrating the number of modules and the number of nodes within each module detected.

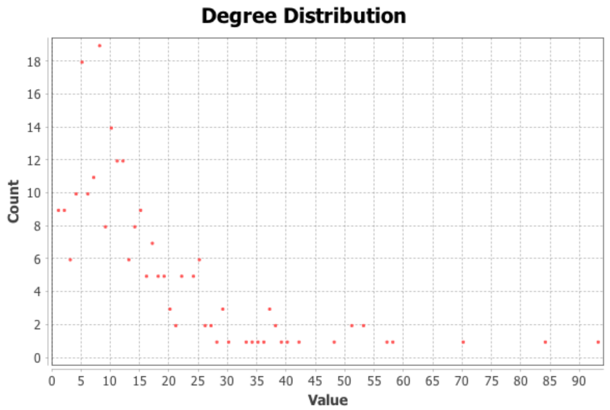


Modularity class 0 has 48 nodes; class 1 has 61 nodes; class 2 has 67 nodes; and class 3 has 59 nodes, showing that modularity class 2 has the highest number of species.

The modularity value for the Sanak Intertidal network is 0.336 – this number represents the fraction of edges which are in the given communities, subtracting the expected fraction if the edges were distributed in a random fashion. The modularity in our network was calculated to be 0.336, which indicates that the majority of the species (nodes) within the communities are not densely connected together – this could be attributed to the fact that only a small number of communities were detected, all of which included many species. If the communities were to be smaller, it may have been found that they were more densely connected.

This is one method of community detection – however, modularity is not capable of detecting smaller communities due to a resolution limit – this means those that would be detected as a small community within the ecosystem (for example, if detected through the Girvan-Newman community detection algorithm) are not identified as a community when using the Modularity class, and these nodes are just put into an already existing module.

Additionally, the modularity class only shows 4 communities, which seems rather small when we take into account the size of the dataset that is being investigated – with 235 different species in the food web, it is expected that there would be a larger number of smaller communities that have more dense connections between the nodes within those communities.



The above graph shows the degree distribution across all of the nodes in the network. This indicates how many neighbours each node has, which tells us how many trophic links each species in the ecosystem has. The average degree was found to be 14.715 – this is largely accounted by the nodes that have many connections through consuming or being consumed by other species. The graph shows that the node with the highest degree had a degree count of 93 – this was found to be Detritus complex, indicating it is the node with most links between other nodes, across the network. In most cases, species with a lower degree tended to be those that were in a higher trophic level in the ecosystem.

There were nine species that had a degree of 1, indicating they were each only connected to one other species in the food web. One of these species includes *Caloplaca* (a genus of lichens) which existed in the Sanak Intertidal community solely as a prey for *Littorina* (a genus of small sea snails). The species with a degree of 1 did not have the roles of predators in the ecosystem – instead, they all had trophic links to other species such that they were the ones being consumed.

IV. APPROACH

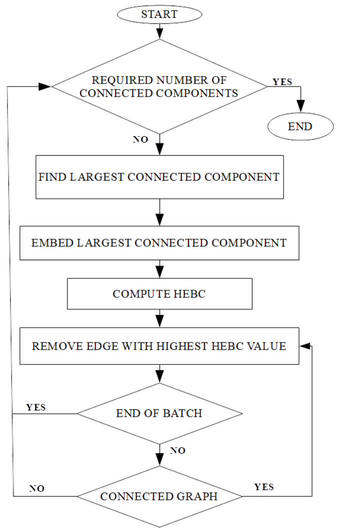
The investigation in question involved executing two algorithms on the Sanak Intertidal Food Web dataset. The two algorithms that were chosen for this were the Girvan-Newman community detection algorithm, and the Eigenvector Centrality algorithm. Girvan-Newman was used to detect the communities in the network, and the Eigenvector algorithm was used to measure the centrality or 'importance' of certain nodes within the network.

Girvan-Newman works by detecting communities whose nodes are more densely connected to each other – it does this by removing the edges between them, until no edges remain in the network. The betweenness (as given in Gephi) is calculated for each edge, and the edge with the highest value is removed. The betweenness is then recalculated for the remaining edges, and again is the edge with the highest value removed.

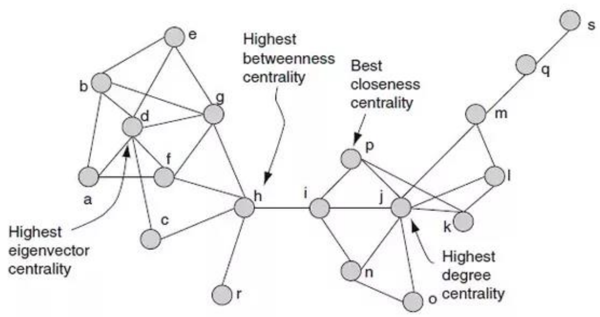
The goal here is to illustrate the betweenness by focussing on edges that are most likely between communities. This helped to identify the different communities that existed in the dataset, which allowed for analysis and evaluation for any implications this would have in a real-life context.

The Girvan-Newman was installed via an external plugin as it was provided by Gephi, allowing its application and execution to and on our network. It was developed 'as a part of a practical internship at the university of Hagen at the department of theoretical computer science'.

The image below shows, in general, how the Girvan-Newman community detection algorithm works.



The Eigenvector algorithm measures the influence or importance of a node in the network. It is based on a 'scoring' system, where relative scores are assigned to all of the nodes in the network. This relies on the notion that if a node is connected to a high-score node, that node itself will be assigned a higher score, rather than if it had the same number of connections but to lower-scored nodes. A high score – as determined through the Eigenvector algorithm – indicates that the node that holds that score is connected to other nodes which themselves have a high relative score.



The example network indicates the node with the highest Eigenvector centrality – it is important to note that Eigenvector centrality and degree are not necessarily equivalent – as shown in the network, where one node (d) has the highest Eigenvector centrality but another node (j) has the highest degree centrality.

This was helpful in identifying the nodes that are deemed important in the network, allowing us to carry out further investigations such as, how would the network be affected if the important nodes were to be removed the ecosystem? This provided useful insights into the implications that such an effect could have in a real-world setting, as in an ecosystem, it is relatively easy for the balance within it to be thrown off, through the reduction in certain species' populations (those that are more central or important to the network), or even through the introduction of a new species within the network, which could also cause imbalances or breakdowns in the network.

Other statistics were also calculated prior to applying these algorithms, in order to gain an understanding of certain properties of the network. One of these included the average path length, which is defined as the average number of steps along shortest paths across all pairs of nodes with an edge between them. This was an important statistic to have calculated before the application of the algorithms, as it is an important statistic to be able to recalculate after certain nodes (species) are deleted from the network to investigate the effects. Since the edges in the network represent trophic links (which in turn shows the flow of energy), it would mean specfic important nodes (such as *Homo sapiens*) being deleted would be expected to cause certain shortest path lengths between remaining nodes to increase, requiring more hops per for every short path route that the specific node was involved in, thereby reducing the energy that is transferred between species.

Less energy being transferred between trophic levels has an impact on the ecosystem, as this means the organism partaking in the consuming will not receive as much energy as usual and hence, will be required to consume a larger number of species to gain that missing energy. This in turn reduces the population of the prey, which can snowball into more extreme problems in the ecosystem over time.

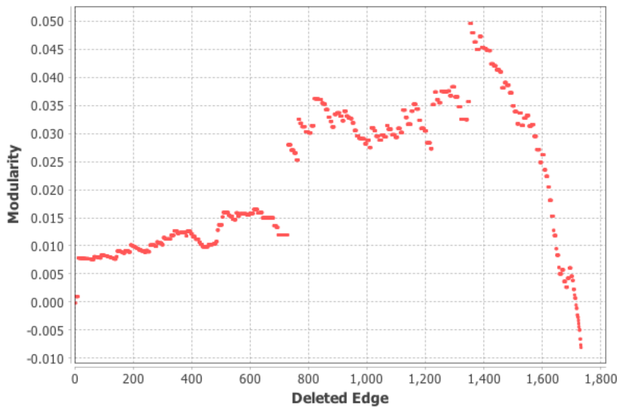
The Girvan-Newman algorithm was used to find the communities in the network whose nodes were more densely connected. We expected to find more communities through this algorithm than when using the Modularity class function in Gephi – and after having executed the Girvan-Newman algorithm, we wished to revisit statistics that we had previously calculated and redo them, in order to detect any similarities anddifferences, so that it could subsequently be analysed, allowing explanations to be made and conclusions to be drawn.

V. Results

A. *Girvan-Newman Community Detection Algorithm*

The Girvan-Newman algorithm was executed on the network through Gephi, following other statistics being calculated. This showed that there were 173 communities detected in the network, which was much greater than the number of modules found through the modularity class, which was 4. This difference can be explained through the limitations of the modularity function, as it is incapable of detecting smaller communities in a network due to a limit in resolution, meaning it can only group communities within a certain range of values.

We expected to find more than 4 communities after executing the Girvan-Newman algorithm – however, detecting 173 communities was much more than initially expected, especially for a network with only 235 nodes. A community in an ecosystem is an association of populations that is formed when two or more species occupy the same geographical area, in a particular time. Since many organisms habituate an ecosystem – each with their own times of activity – it justifies the smaller communities that are formed through their interactions, as not all organisms interact directly with each other due to the nature of a food chain.



This graph shows how modularity of the network increases as edges with the highest betweenness centrality are deleted up until approximately 1350 edges are deleted – the modularity then takes a steep fall. The maximum found modularity was 0.04978, which contrasts siginificantly from the value found for the entire network through the modularity class function, which was 0.336. The closer this value is to 1, the more densely connected the nodes are. A modularity value of 0.336 indicates that the nodes are not too tightly connected to each other, although they were more densely connected in this method than when compared to the Girvan-Newman algorithm was carried out, as evidenced by the very low modularity values (for each node) that were calculated through this method.

Modularity is defined as the extent to which nodes within communities are densely connected to each other. The modularity was much greater prior to applying the Girvan-Newman algorithm – this is expected, as the modularity class function only found 4 modules (communities) and hence the nodes (species) within those modules were more densely connected to each other. This could have also attributed to the fact that there was a large number of species in each community, allowing several food chains to exist within it, and therefore a higher number of trophic links (edges).

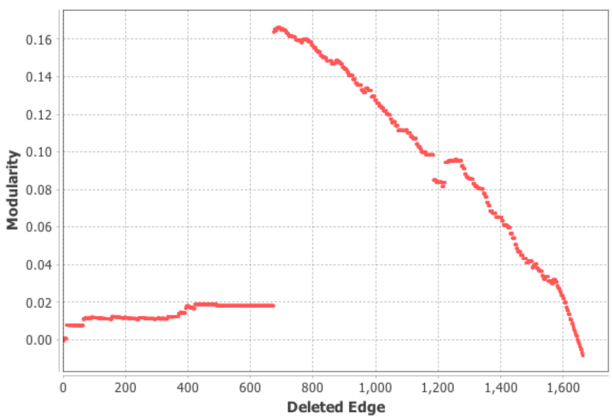
The Girvan-Newman algorithm detected 173 communities, meaning there were less species within each community – therefore, the number of dense connections between nodes in communities also decreased, due to the limited number of nodes in each community. Since each community has a lower number of species – and therefore food chains – within it, each of the connections between different communities are those that connect food chains together, where an organism would be involved in multiple food chains, acting as the node that edges two or more communities together.

This shows that even within the same ecosystem, there are sub-communities that form due to the interactions with the different species, and also illustrates the reliance of organisms on other species that belong to those different communities – all of which propgates the energy transfer throughout the ecosystem, enabling its sustainability and longetivity. From this, it is reasonable to conclude that the links between species within their own communities are the ones that have a major significance, as it allows each of the individual food chains to begin (with the producer being consumed by the organism in the immediate-higher trophic level). However, the links between each of the communities also play a huge role in the maintenance of the ecosystem, as this allows species belonging to different food chains (i.e. a part of more than one food chain) to interact through consuming, enabling energy to be transferred and life-cycles to continue.

The *Homo sapiens* node was calculated to have a high betweenness centrality – the 3rd highest in the network. This indicates it is one of the most important nodes (species) in the network, suggesting that it is involved in many of the shortest paths taken, when concerning the other nodes in the network as a source and target.

Since we were also studying the role of humans within the food web, we decided to delete this node from the network to investigate the impacts their absence would have on the ecosystem, especially after it was discovered by a previous research paper that the introduction of humans to the ecosystem appeared to have no long-term extinction effects on other species in the food web.

After deleting the *Homo sapiens* node, the Girvan-Newman algorithm was executed once again, in order to see if there were any changes from the previous calculation. It was found that the number of communities had decreased from 173 to 76, representing a disappearance of 97 communities in the network, meaning the resulting 76 communities had more nodes in each.

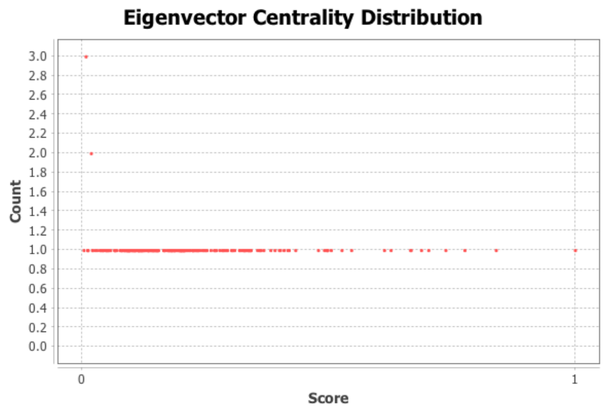


The graph shows how the modularity values change as edges are deleted from the remaining network (the *Homo sapiens* node is not present in this network). At first, as edges are deleted, modularity increases steadily, indicating the nodes within communities are more cohesively connected together. However, a large spike in modularity is detected after approximately 680 edges are deleted, resulting in a peak modularity of 0.1669. As additional edges are deleted, modularity continues to decrease (until approximately 1200 edges are deleted – modularity rises and subsequently falls again), showing that the nodes within communities become less densely connected.

The average path length as calculated to be 2.359 before the *Homo sapiens* node was deleted. After deletion, it was calculated to be 2.391, an difference of 0.032 – a 1.36% increase. This means that after deleting a node that acted as a bridge between two other nodes increased the number of hops that needed to be done by 1.36%. This was an increase that was expected, as deleting the node that had one of the highest betweenness centralities would cause shortest path lengths for the remaining nodes to increase. A real world implication of this is that there is less energy transmission overall throughout the ecosystem, as more edges (trophic links) need to be 'hopped' through, resulting in less energy being transferred to organisms, requiring them to gain the energy that they have not received through more consuming of other organisms.

B. Eigenvector Centrality Algorithm

The Eigenvector centrality algorithm was executed on the original dataset, with all nodes (and edges) restored in the network. This algorithm was carried out to find out the importance of the nodes in the network, in order to find out whether removing one of the important nodes (as *Homo sapiens* are expected to be) would affect the network in any way.

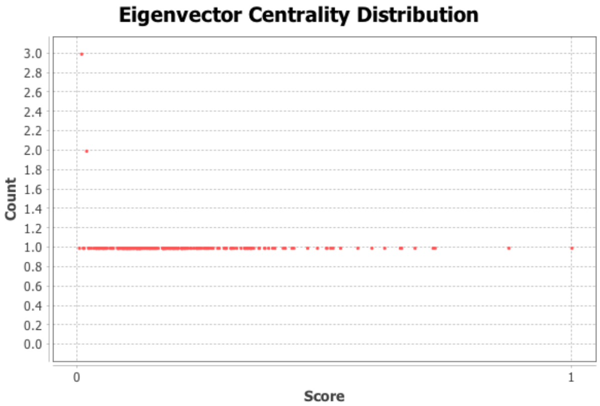


The graph shows the Eigenvector centrality values across the network. Only one node was found to have a value of one, indicating that it was the most important node in the network – this was *Detritus complex*, which was one of the primary sources of food for many organisms living in the ecosystem. The greater the Eigenvector value of a node, the more neighbours that it had that also had high Eigenvector values – this means that the species that were more central to the ecosystem (i.e. had higher values) had trophic links to other species that were also of high importance in the ecosystem.

As the Eigenvector score in the graph increases, there are fewer nodes in the network with that score. Throughout the network, all nodes each had a unique Eigenvector score, excluding 5 nodes – out of these nodes, two had the same score as each other and the remaining three nodes also had equal scores relative to each other.

The various scores spread throughout the network suggests that most of the species in the network have different levels of importance, with the species that have the lower scores (and therefore less central to the network) are the ones at higher trophic levels – these are the organisms that mostly focus on predation, and in some cases, have no other organisms that consume them (there are no others in a higher trophic level in that particular food chain).

The *Homo sapiens* node had an Eigenvector score of 0.7756, the 3rd highest score in the network, demonstrating humans' high level of importance in the ecosystem. Due to this reason, this node was deleted in order to investigate any changes in the Eigenvector scores.



The graph shows the Eigenvector centrality distribution across the network after the *Homo sapiens* node was deleted. The graph looks similar to that of which was illustrated prior to the deletion – however, there are a few differences, as it was discovered that some of the higher scoring nodes were given an even greater score after the *Homo sapiens* node was deleted, showing that their level of importance became more significant after an already important node was removed from the network. It can be extrapolated that, as important species are continuously removed from the network, those species that were of lower importance (through a lower Eigenvector score) naturally have their Eigenvector score increased, thereby showing that they become gradually more important and central to the ecosystem. This is expected since they become more central as there are fewer organisms, increasing their importance relative to the sustainability and maintenance of the remaining ecosystem.

Deleting the *Homo sapiens* node also means that the edges between all of its neighbours would also be affected – as it was found that the links between humans and other species indicated that humans were the predators in these scenerios, meaning the consuming was being carried out from their side. With the absence of an important predator, there is a massive reduction in the amount of organisms being consumed, as humans are significant contributors towards the sustainability of the entire food web, by keeping the populations of various species controlled.

This also means that since energy will no longer be transferred to humans (due to the lack of a trophic link), organisms have more energy that may be passed on to other predators that feed on them – or they can use this additional energy to reproduce, causing their populations to increase rapidly (especially if a greater number of species are reproducing), which could potentially affect the state of the ecosystem.

VI. Conclusions

The Girvan-Newman algorithm was used to detect communities that were otherwise not found (via the modularity class function in Gephi), allowing us to discover the impact of removing humans from the network. The Eigenvector algorithm was used to find the nodes that were more central to the network by calculating their Eigenvector scores, which is dependent on the scores of the nodes' neighbours – meaning that if a node had a higher score, it was due to it having edges to other nodes that also had high Eigenvector scores.

Upon removing humans from the network, it was also found that the average path length for the entire network decreased by – albeit small – a percentage. This meant that since the node that acted as a bridge (involved in the shortest path) between different nodes was removed, extra 'hops' needed to be made in order to get from a source to a target node – and in the context of the food web, it means more energy is lost at each trophic level, thereby reducing the overall amount of energy that is transferred in the ecosystem.

In conclusion, it is clear that humans play a very important role in the Sanak Intertidal ecosystem ever since their initial introduction. As they play the roles of highly omnivorous consumers – meaning that they feed on both animals and plants – they are involved in many interactions between several other species in the ecosystem, allowing the maintenance of the entire food web by keeping the populations of various species at a reasonable number.

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