Project Paper: Analysis of The Endangered Species Trade

Aarti Barakale
Computer Science, 572 University of Calgary
aarti.barakale@ucalgary.ca 30061569

Victor Dong
Computer Science, 572 University of Calgary
victor.dong1@ucalgary.ca 30069499

Fabian Pradipto
Computer Science, 572 University of Calgary
fabian.pradipto@ucalgary.ca 30067873

Abstract:

Recent lockdowns have led to many people picking up outdoor guides and rediscovering the joy of nature. With beautiful and diverse wildlife across the country to discover, who would want to stay indoors? Although captivating, the natural world is facing pressure from the wildlife trade. Hundreds of live animals are traded each day. About 200 million live animal trades have taken place globally since 1975 [1]. In 2003 alone, over legal trades of 7.5 million animals were loaded onto boats and shipped across the world! But where do these animals go? And what are they used for? To answer those questions, we dove into data from the CITES Trade Database (2) for 2020 on the trade of live animals. We found influential and non-influential countries trading animals for different purposes due to different reasons, for which we applied degree centrality and modularity techniques to understand more by answering three research questions: 1. Can we identify the dispersion of these animals within the world? 2. What are the leading cause/purpose(s) for a species to be exported and imported? 3. Which species within each appendix is imported the most, and who is the leading importer of these animals? Our research helped us answer these questions to a certain extent, and we can now identify why some countries majorly export species that are not native to that region and which countries are visibly impacted by the trade law.

Keywords— taxons, appendix

Research questions:

Given how vast the wildlife trade industry is, many methods and perspectives can be analyzed. Based on our data and interests regarding the legal wildlife trade, we have decided to ask the following questions:

1. Can we identify the dispersion of these animals within the world?

Our first research question is intended to give a broad and brief overview of the trading network. Knowing where the species ends up, we can identify any trading patterns and active contributors participating in these trades. From there, a more thorough analysis can be conducted to identify what and why those species are imported.

2. What are the leading cause/purpose(s) for a species to be imported or exported?

Our second research question intends to explore the primary causes for a taxon to be imported/exported. By highlighting these variables, we hope to help the readers to come to their own conclusion and decide whether or not the trades of these species are justifiable or exploitative.

We plan to visualize this network by focusing on the top 2 dominant purposes for importers and exporters and then identify the countries that heavily participate for the following purposes. We will also use charts to examine this issue from several perspectives.

3. Which species within each appendix is imported the most, and who is the leading importer of these animals?

For context, CITES categorizes its taxons using appendices that indicate their level of endangeredness (Appendix I, II, and III), with appendix I being the most endangered. Hence, identifying the species and common players in the trading network allows us to closely monitor any patterns or changes that may threaten these species. Although appendix I needs the most attention at the moment, we thought it would be important to look into the other two appendices to make sure those animals don't end up being critically endangered. Please note that there also exists taxons in Appendix N, which are non-CITES-listed species that are not necessarily endangered but require stricter trade measures by certain countries [3]. We will include this small subset in the network graph as a whole, but we will not analyze them further, unlike the other three appendices.

We plan to address this question by segmenting the data by appendix and using the network format to find the taxons. After that, we will conduct a more thorough analysis of the specific taxons to identify the active importers and types of imported products.

Introduction:

Several wild animals are captured, bred and traded every year for various purposes, including food, traditional medicine and as exotic pets. Animal suffering occurs, and zoonotic infections can spread at every stage of the trade or, on the flip side, places with similar species, endangered, are restored in number. The CITES Trade Database used in our Social Network analysis contains information on the taxons' importer countries and exporter countries along with the quantities, purposes and sources of their trade.

Dataset description:

Our dataset contains trade information on endangered species managed by CITES [1].
Dataset Title: CITES Trade Database (2020).
Dataset Source: https://trade.cites.org/

This data is downloaded directly from the CITES trade database, which stores all legal trade of endangered species dating back to 1975, but we will be specifically looking at the year 2020. This data is downloaded in CSV format.

- the **exporter** and **importer** (countries or territories);
- the **source** of species or specimens traded (e.g. wild-sourced or ranched specimens);
- the **purpose** of the trade(e.g. commercial or for botanic gardens);
- the **trade term** (e.g. live individuals, skins, etc.); and
- the **taxon** (i.e. genus, species, or subspecies) of interest.

Querying at higher taxonomic levels is also possible (i.e. order, class, etc.), which would return records reported at that taxonomic level (e.g. as class ‘Reptilia spp.’) as well as those reported at lower taxonomic levels (e.g. all reptiles).

Conference of the Parties (or COP) to review progress and adjust the lists of protected species, which are grouped into three categories with different levels of protection:

Appendix I: Includes the world’s most endangered plants and animals, such as tigers and gorillas. International commercial trade in these species, or even parts of them, is completely banned, except in rare cases such as scientific research.

Appendix II: Contains species like corals that are not yet threatened with extinction but could become threatened if unlimited trade were allowed. Also included are “look-alike” species that closely resemble those already on the list for conservation reasons. Plants and animals in this category can be traded internationally, but strict rules exist.

Appendix III: Species whose trade is only regulated within a specific country can be placed on Appendix III if that country requires cooperation from other nations to help prevent exploitation [3].

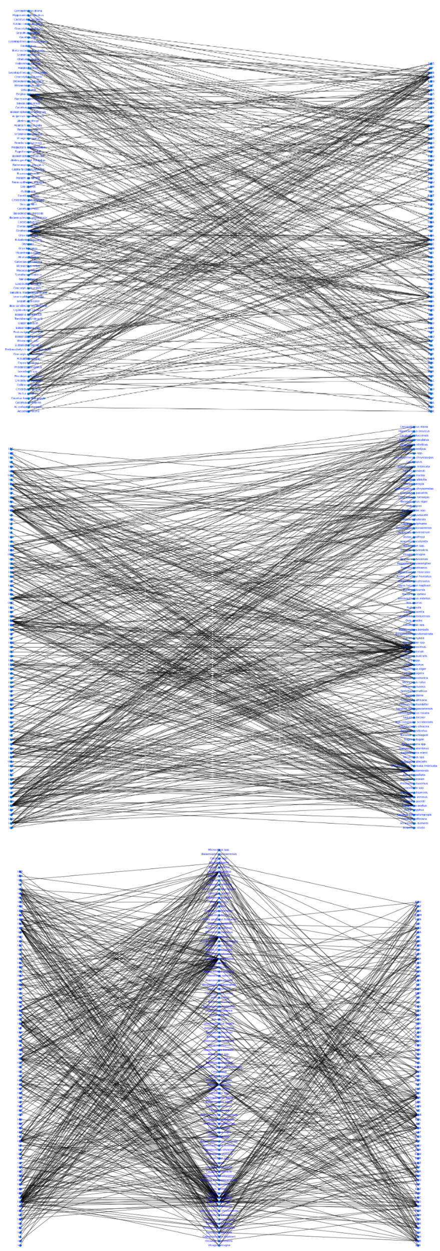
Data cleaning:
Since the data is taken from an official source that is open to the public, the format and content are relatively clean. Hence we expect that we do not have to do extensive data clean-up. The cleanups we have done are listed below and were done through Tableau and the Jupyter notebook.

- Removed the data where the imported/exported quantity was not included
- Removed plant products from the raw data (.csv) to focus only on animal and animal products.
- Removed redundant columns that will not be included in the analysis (i.e. the “Origin” column).
- We converted the importer and exporter column to include if they are an exporter or importer.
- Further, we converted all the country codes to full form for legibility and consistency.

Network Construction:

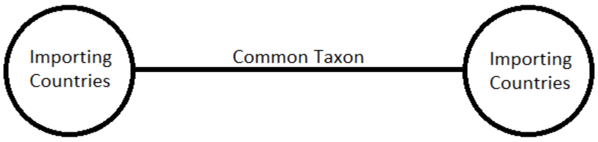
In its raw form, this network can be displayed as a tripartite network where there are three different types of nodes (importing countries, exporting countries, and taxons) which are connected by an edge if a country has imported/exported that specific taxon. The visualization below demonstrates how a tripartite network can be constructed using the first 1000 entries.

As you can see, visualizing the data in the tripartite form can get quite dense. When we use the entire dataset, this denseness issue will be exacerbated, making it harder for us to infer anything from it. Dr. Towlson brought up this potential issue during our project consultation. She suggested we create several unipartite projections to make this network more manageable.



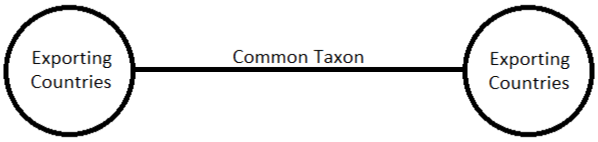
Projections:
The following are the four projections that have been created:

Projection 1 - Importing countries-importing countries connected by the common taxon:



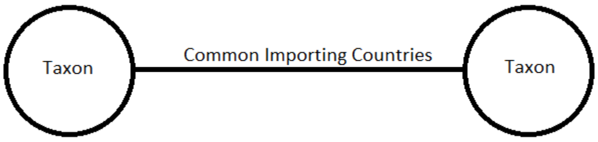
For the first projection, all the importing countries will be displayed as the node, and an edge will be created between two nodes if they have imported the same taxon. These edges are also weighted where every common taxon the two nodes have imported counts as 1 in weight.

Projection 2 - Exporting countries-exporting countries connected by the common taxon:



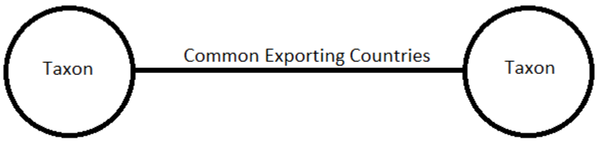
For the second projection, all the exporting countries will be displayed as the node, and an edge will be created between two nodes if they have exported the same taxon. These edges are also weighted where every common taxon the two nodes have exported counts as 1 in weight.

Projection 3 - Taxon-taxon connected by importing countries:



For the third projection, all the imported taxons will be displayed as the node. An edge will be created between two nodes if the same countries have imported them. These edges are also weighted where each common importing country the two nodes have imported counts as 1 in weight.

Projection 4 - Taxon-taxon connected by exporting countries:

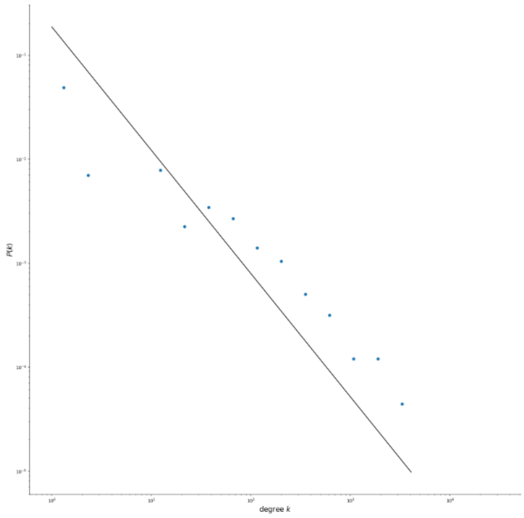


For the fourth projection, all the exported taxons will be displayed as the node. An edge will be created between two nodes if the same countries have exported them. These edges are also weighted where each common exporting country the two nodes have exported counts as 1 in weight.

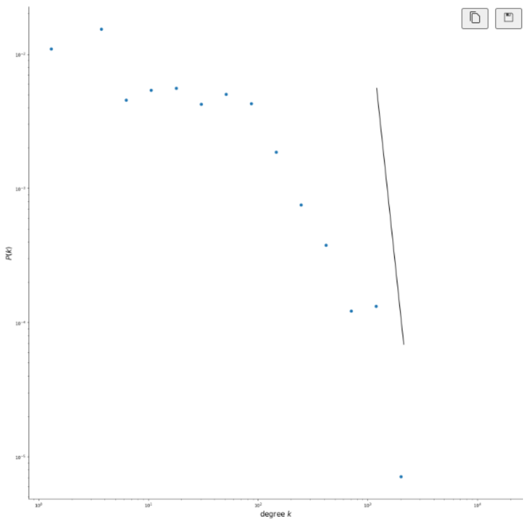
Basic statistics:
Given the four projections we presented above, each one of these projections will have its own measurements.
With our first projection being importing countries connected by common taxons, we have 110 nodes and 3572 edges. With this projection, we have 1 component and an unweighted clustering coefficient of 8.39×10^{-1}, a weighted clustering coefficient of 2.03×10^{-2} and an average path length of 1.41. Our second projection is exporting countries connected by a common taxon. We have a total of 134 nodes, 4071 edges and three components with the respective size being: [132, 1, 1]. This projection yields an unweighted clustering coefficient of 7.93×10^{-1}, a weighted clustering coefficient of 2.36×10^{-2} and an average path length of 1.53 for the largest component. The third projection is taxons connected by common importing countries with 1423 nodes, 425072 edges and 1 component. This projection yields an unweighted clustering coefficient of 8.59×10^{-1}, a weighted clustering coefficient of 3.33×10^{-2} and an average path length of 1.59 for the largest component. The fourth projection is taxons connected by common importing countries with 1487 nodes, 272116 edges and three components. This projection yields an unweighted clustering coefficient of 8.40×10^{-1}, a weighted clustering coefficient of 3.24×10^{-2} and an average path length of 1.78 for the largest component.

Degree distribution (including fit):

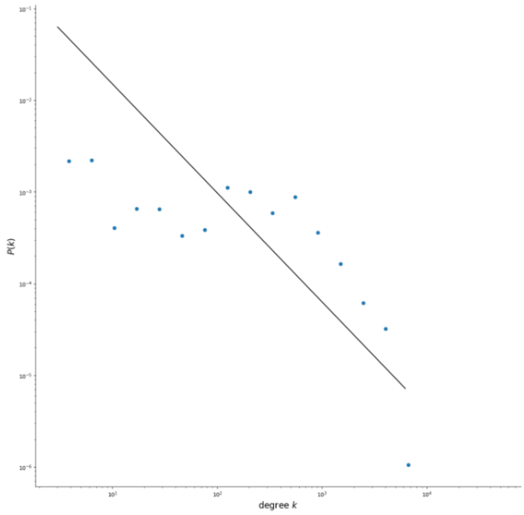
Importing countries connected by common taxon:



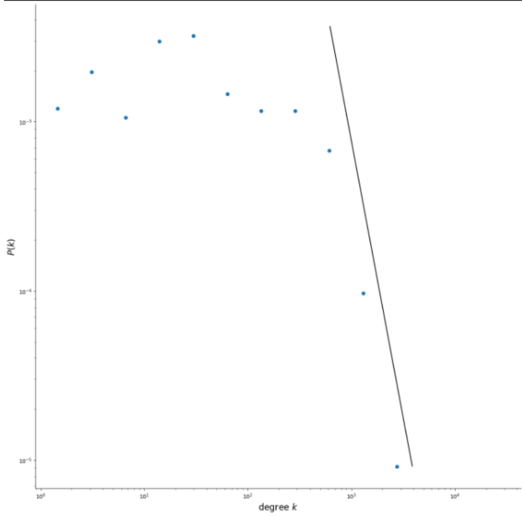
Exporting countries connected by common taxon:



Taxons connected by common importing countries:



Taxons connected by common exporting countries:



Average Clustering coefficient:

Importing countries connected by common taxon:
Unweighted average Clustering Coefficient: 0.8389847856019887
Weighted average clustering coefficient: 0.02026116735849747
Exporting countries connected by common taxon:
Unweighted average Clustering Coefficient: 0.7927670641830104
Weighted average clustering coefficient: 0.02364623738087388
Taxons connected by common importing countries:
Unweighted average Clustering Coefficient: 0.8592404898918155
Weighted average clustering coefficient: 0.03331391018137013
Taxons connected by common exporting countries:
Unweighted average Clustering Coefficient: 0.8397814983118916
Weighted average clustering coefficient: 0.032388777024829445

In regards to our average clustering coefficient, it is evident that throughout the four projections, they all carry a high clustering coefficient which is indicative that the network is very dense and nodes have high levels of connectivity to their neighbors. This is anticipated as the trading networks are interconnected, and countries tend to import and export many taxons with similar quantities. This leads us to see that the network has fewer hubs in smaller sizes and mimics the structure of a random network.

Average Path length:

Importing countries connected by common taxon:
Average shortest path length: 1.41
Exporting countries connected by common taxon:
Average shortest path length for component 1: 1.53
Average shortest path length for component 2: 0
Average shortest path length for component 3: 0
Taxons connected by common importing countries:
Average shortest path length: 1.59
Taxons connected by common exporting countries:
Average shortest path length for component 1: 1.78
Average shortest path length for component 2: 0
Average shortest path length for component 3: 0

With the projections, the path lengths are relatively small which indicates that countries within our network all import and export similar taxons.

Null model comparison:

Measure	Importing countries connected by common taxon	Degree Preserving model
<Clustering coefficient>	8.39×10^-1	8.25×10^-1
σ Clustering coefficient		8.75×10^-4
<Shortest Path Length>	1.41	1.41
σ Shortest Path Length		3.39×10^-3

Measure	Exporting countries connected by common taxon	Degree Preserving model
<Clustering coefficient>	7.93×10^{-1}	7.60×10^{-1}
σ Clustering coefficient		1.56×10^{-3}
<Shortest Path Length>	1.53	1.53
σ Shortest Path Length		2.2×10^{-16}

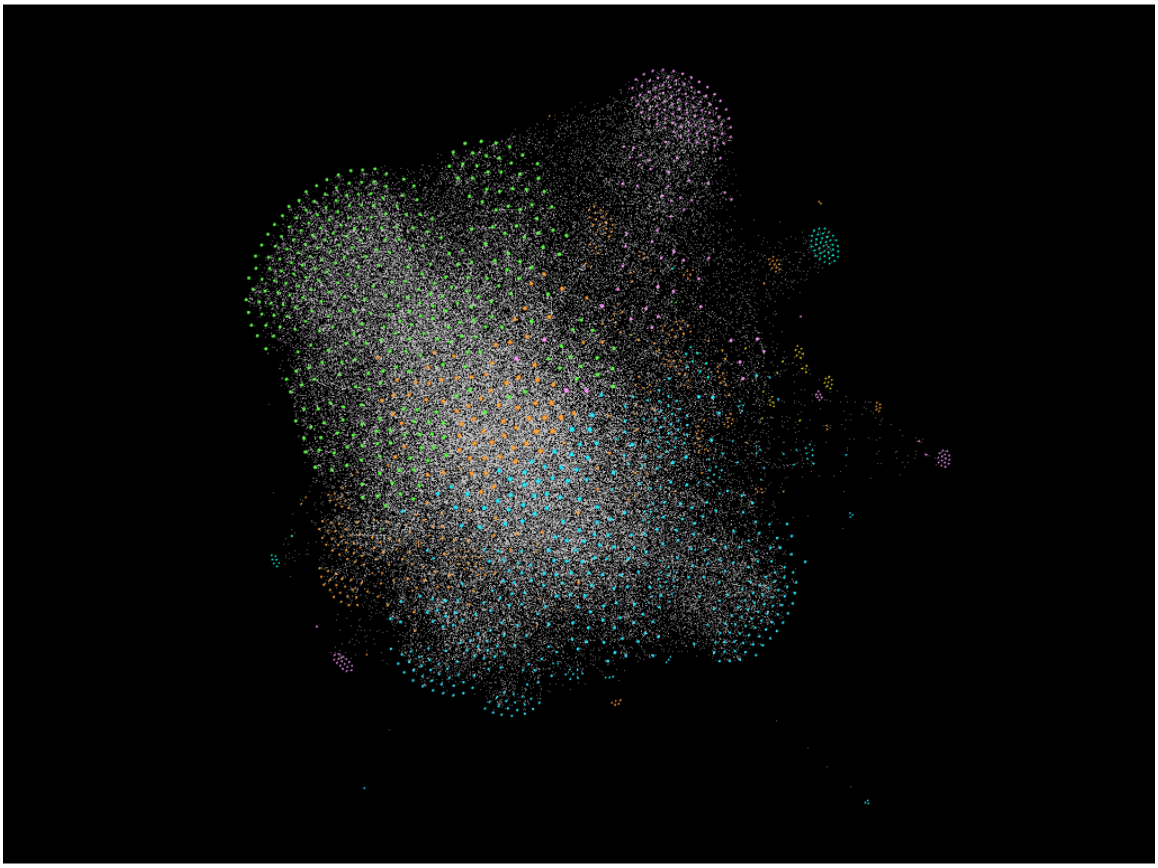
Measure	Taxons connected by common importing countries	Degree Preserving model
<Clustering coefficient>	8.59×10^{-1}	7.86×10^{-1}
σ Clustering coefficient		1.58×10^{-4}
<Shortest Path Length>	1.59	1.58
σ Shortest Path Length		8.48×10^{-5}

Measure	Taxons connected by common exporting countries	Degree Preserving model
<Clustering coefficient>	8.40×10^{-1}	6.41×10^{-1}
σ Clustering coefficient		7.18×10^{-4}
<Shortest Path Length>	1.78	1.78
σ Shortest Path Length		2.22×10^{-16}

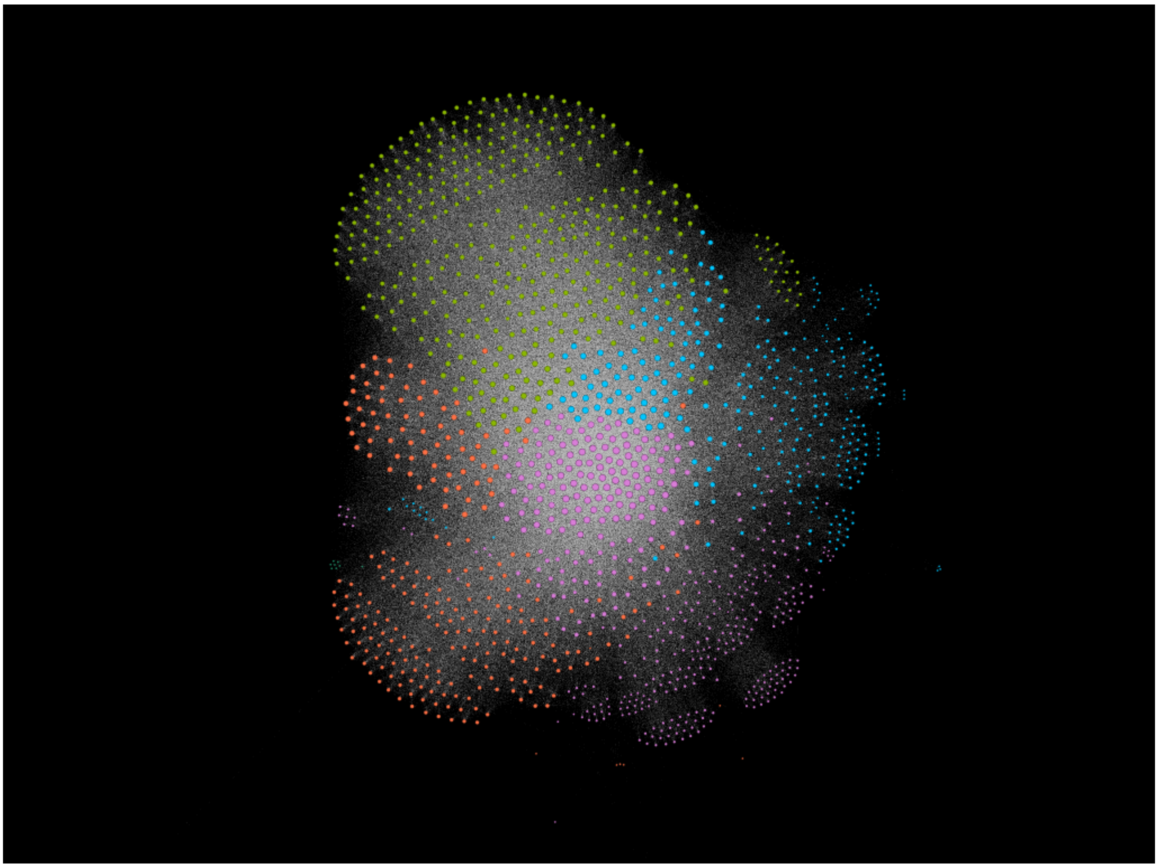
As seen in the degree distributions and the comparison tables for the data and null model using degree preservation, the actual data generates a higher clustering coefficient than the null model generated. This is consistent with each of our projections and shows us that for a model with a similar number of nodes and links, we get a lower clustering coefficient which is expected.

Network visualization:

Taxon-Taxon with edges being the common exporter



Taxon-Taxon with edges being the common importer



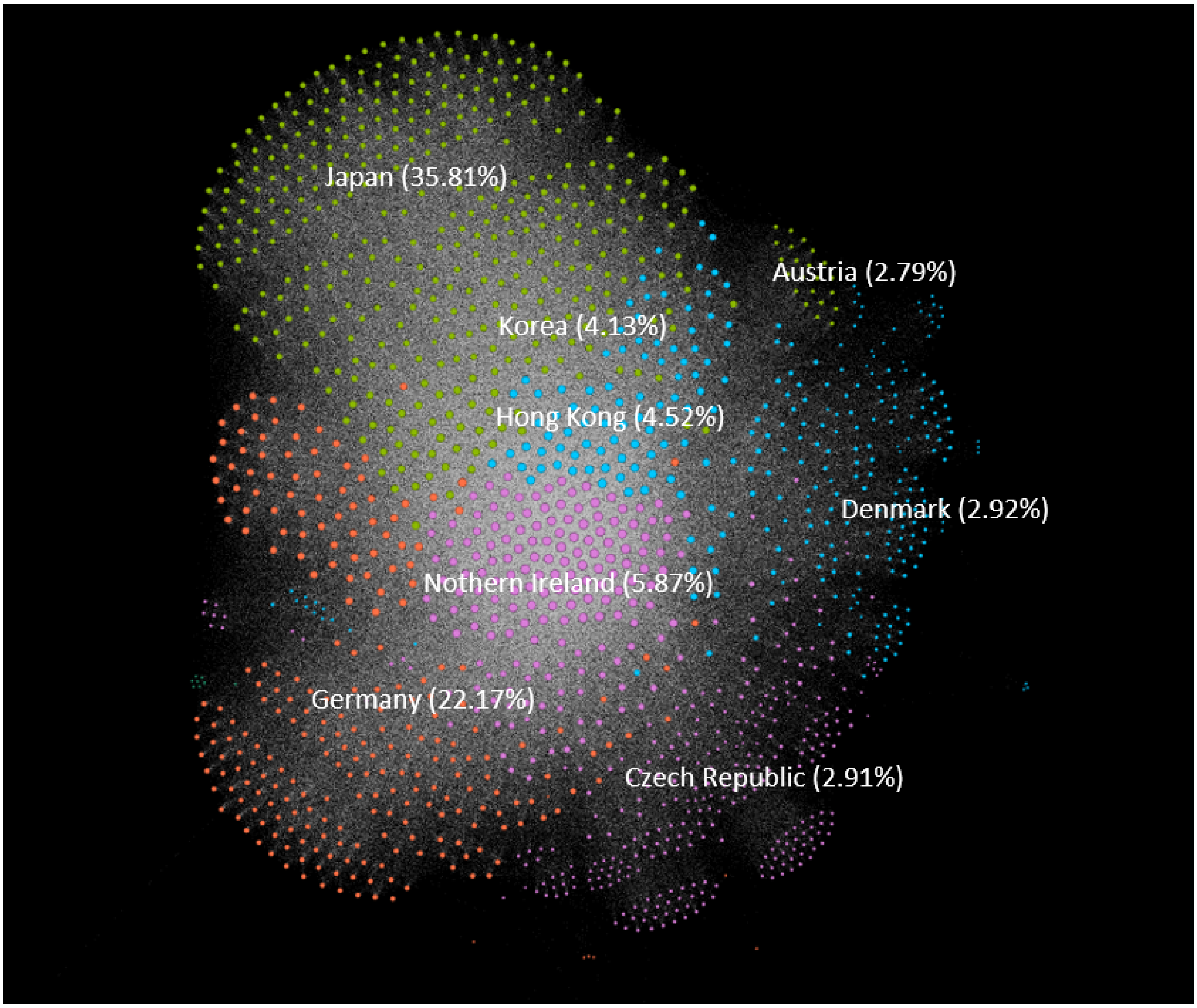


Figure 1.1: Clusters denoting Major importing countries of taxons

Results:

A. Research Question 1

Can we identify the dispersion of these animals within the world?

To determine the dispersions of taxons, we studied two networks, one of the projections of Taxons as nodes and importers as edges and the other of Taxons as nodes and exporters as edges. We used techniques like centrality and modularity to visualize our network, leading to clusterings, seen in the previous section [Basic Statistics] discussing the clustering coefficients of our different projections, which tells us the largest importer of taxons is Japan (35.81%). (Figure 1.1) Upon sorting based on “classes” for the taxons imported in Japan using Power BI, we saw that Mammals and Amphibians are the most imported classes of taxons (Figure 1.2). Japan's reptile, fish and bird imports were among the world's top ten, ranking fourth, sixth and ninth, respectively. Some estimates put the annual import value at over 4 billion yen (about $38.9 million) [7].

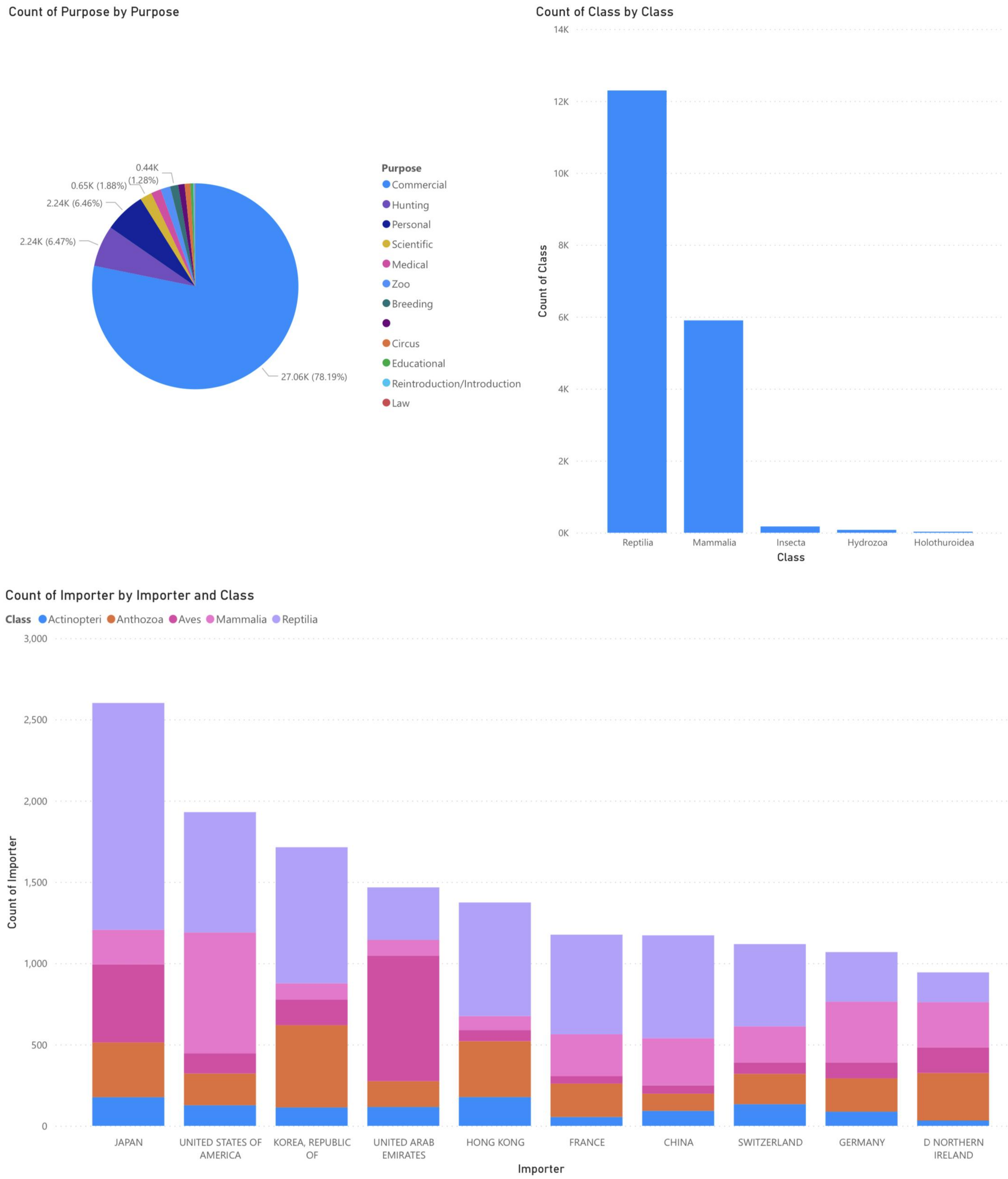


Figure 1.2: Classes imported the most in the countries; Classes imported in importing countries

The imports are mainly for pets, but some are for experimental purposes. For pets, wild foreign reptiles and amphibians are becoming increasingly popular. Rare lizards can fetch hundreds of thousands of yen or more. There are many reasons for their popularity, including that they are quiet and don't need to be walked. This makes them easy to buy, even for people living in apartments.

Germany's vast and diverse landscape presents a fertile breeding ground for a multitude of species. The country is heavily endowed with mountains, rivers, forests, and marshes, allowing different types of animals to thrive. Thus, Germany has a lengthy list of foreign animals introduced over the years [8]. This explains that Germany has been the biggest exporter of taxons over time, as seen in Figure 1.3.

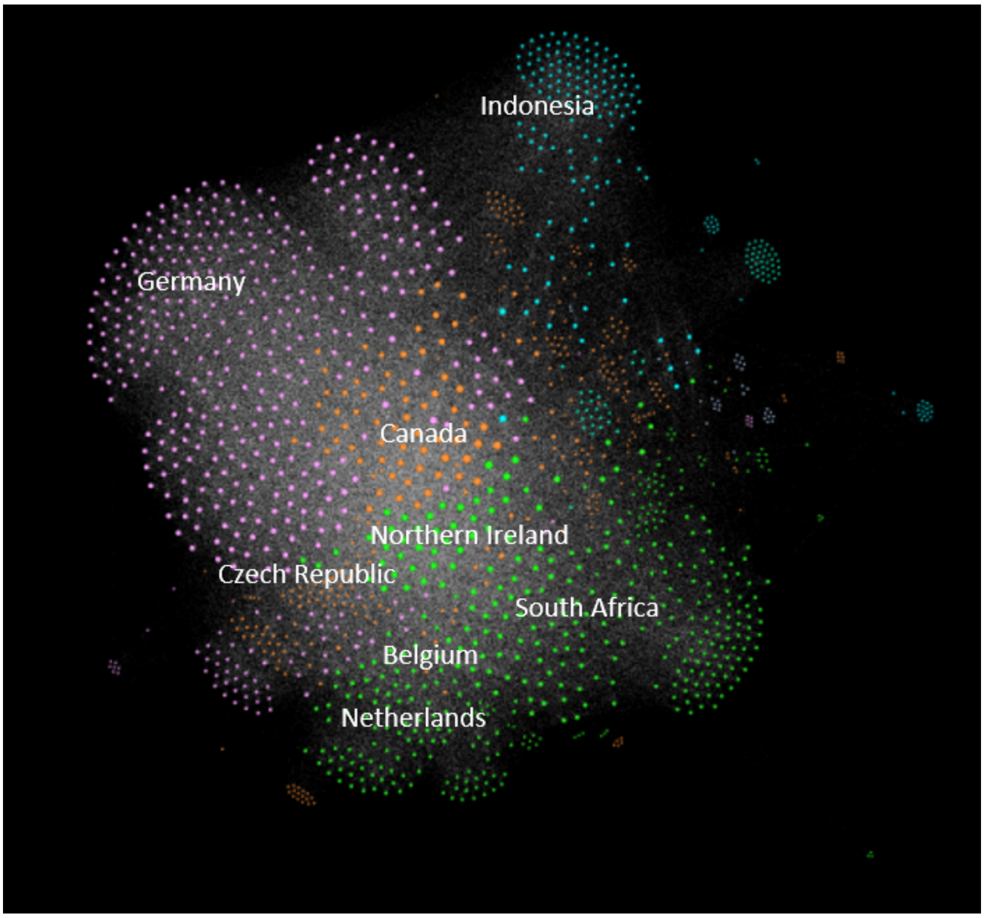


Figure 1.3: Clusters denoting major exporting countries of taxons

Moreover, while interpreting our results, we found that half of the area of Germany is used for agricultural purposes. Almost one million people produce goods worth more than 50 billion euros annually. To cater to these needs, they are seen to strike a balance between imports and exports of agricultural goods, like livestock. This has led to them being the world's third-largest exporter of agricultural goods. The German agricultural industry exports about one-third of its products [9]. Although this will be changing soon, starting in 2023, Germany is to tighten export rules as the Federal Ministry of Food and Agriculture(FMFA) has declared that they will begin restricting the export of various species used for breeding to third countries from Germany to support higher animal welfare [10].

B. Research Question 2

What are the leading causes/purposes for a species to be exported and imported?

Our previous research question led us to want a further knowledge of the primary purpose for exporting these taxons. Using our projections 3 and 4, which are Importing countries with common taxons as edges and exporting countries with common taxons as edges, respectively, we see that upon further filtering on purpose, scientific and commercial reasons stand out the most. In other words, we can say that countries trade (export) the most for scientific and commercial reasons.

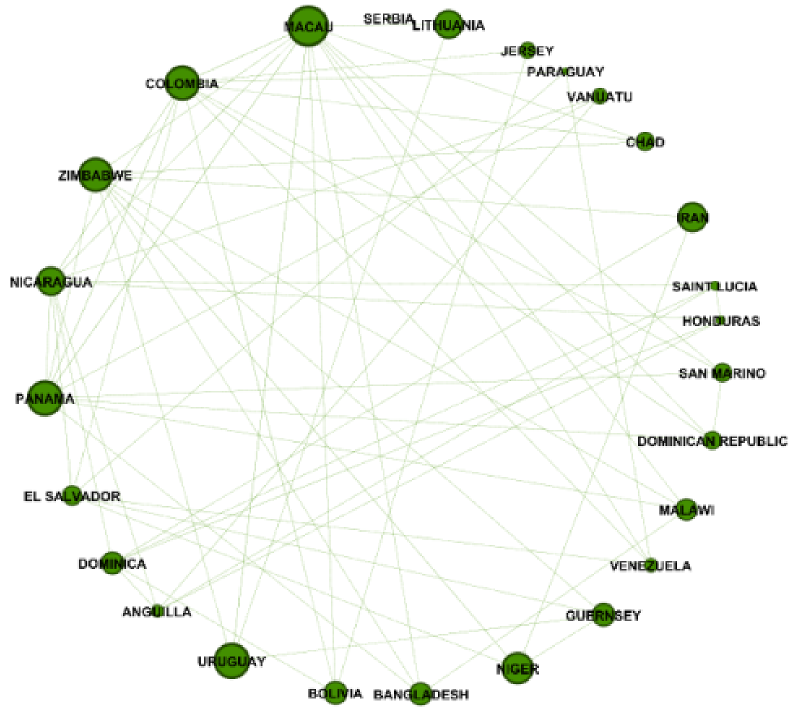


Figure 2.2: Exporting countries for commercial reasons

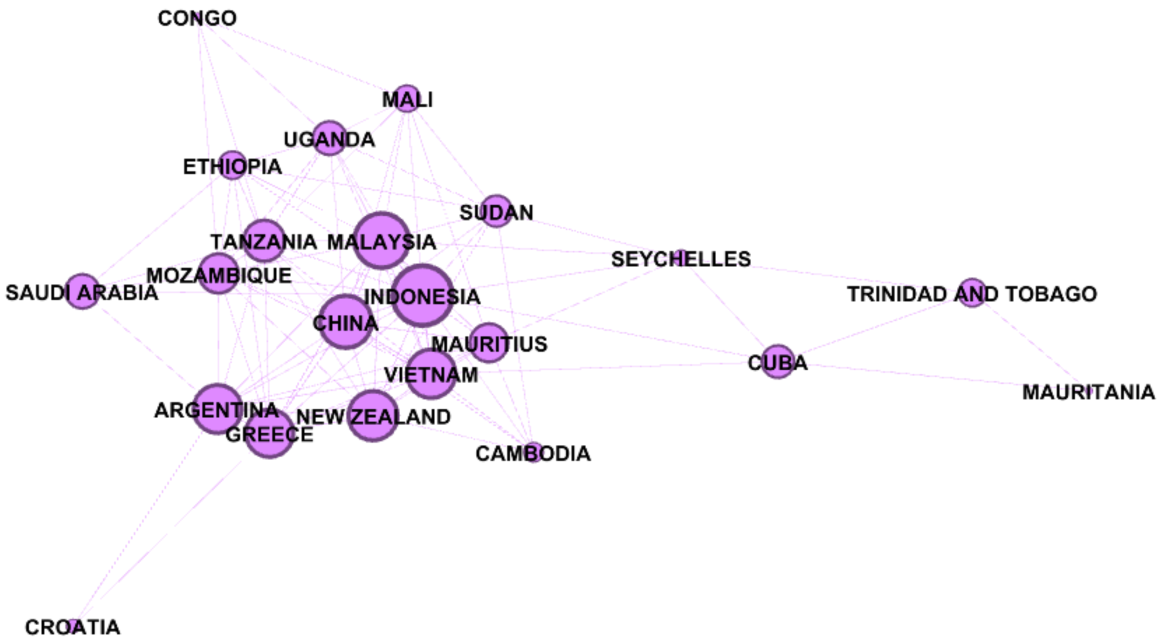


Figure 2.3: Exporting countries for scientific reasons

Leading purpose for species to be exported:

In Europe, it is seen that Italy, Czech Republic, Great Britain, and Belgium, to name a few, export taxons within European countries and to other trading partners [11] for commercial reasons in the primary sector such as crop and animal production, forestry and logging, fishing and aquaculture, which utilize these resources in economic activities and are then sold to consumers or other businesses. Furthermore, after diving deep into the impact of this trade, it was seen that it leads to job creation in European countries and their trade partners.

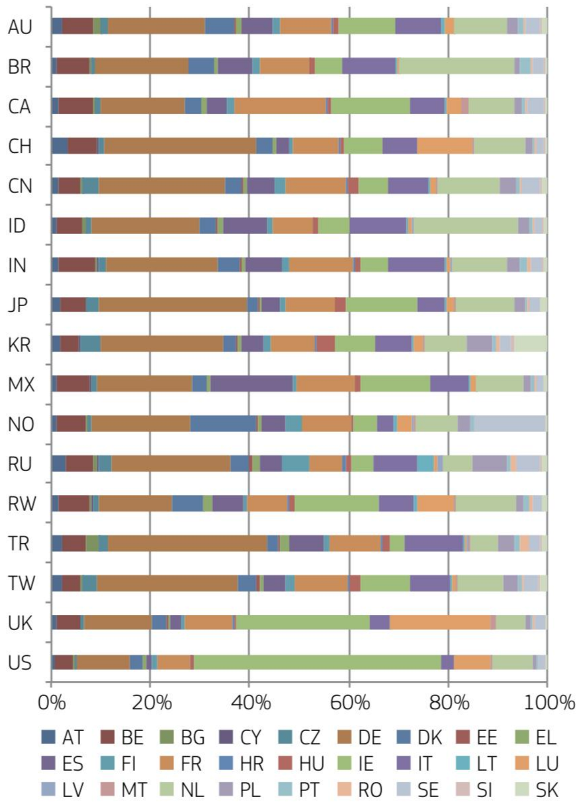


Figure 2.4: Job creation percentage created in trade partners of Europe through commercial exports of taxons (Source: Trade EU)

In 2020, EU exports to the world supported 24.4m jobs outside Europe. Most of the jobs were in China (4.5m), of which German exports drove 1.2m, 580,600 by Dutch exports, 554,400 by French exports, and 379,800 by Italian exports. Germany was the Member State that contributed the most to support employment outside the EU (4.6m jobs), especially in China (1.2m jobs), India (488,200 jobs) and Russia (285,400 jobs) [11].

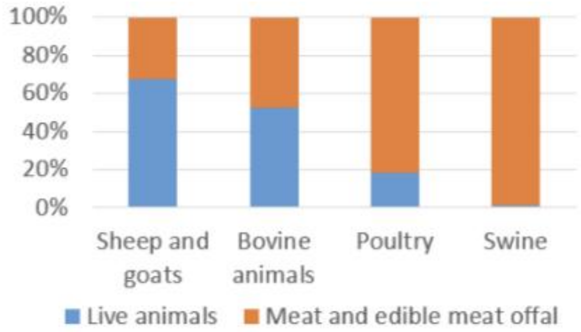


Figure 2.5: Value of EU exports of live animals and meat and edible meat offal in 2020 (Source: Eurostat, ComExt)

Lastly, it is important to note that although live animals are exported the most in our data set, on a larger spectrum, the value of EU trade in processed meat and edible meat offal is much higher than the value of EU trade in live animals. Only the value of EU exports of live sheep and goats and, to a lesser extent, of live bovine animals is higher than the value of EU exports of the respective meat and meat offal, as shown in Figure 2.5.

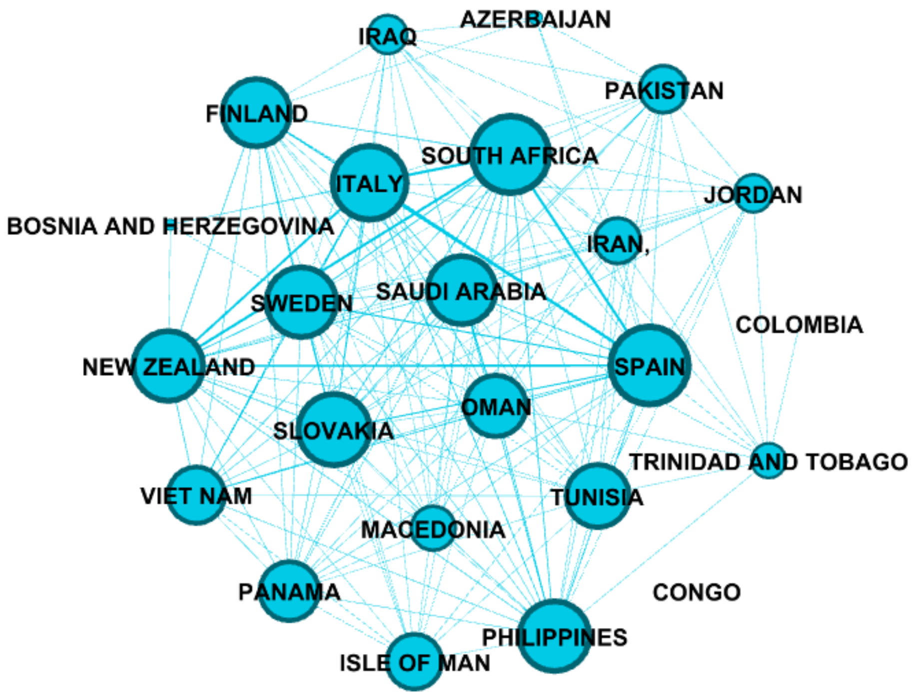


Figure 2.6: Countries that import for zoo purposes

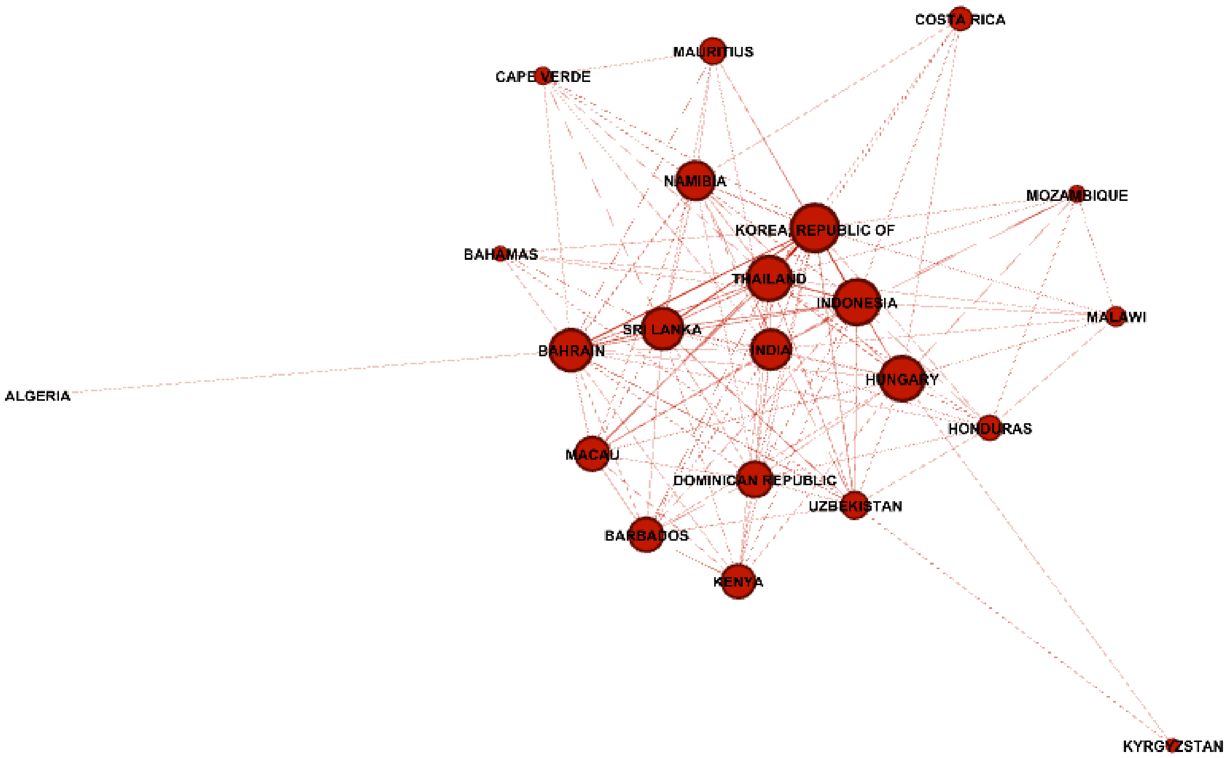


Figure 2.7: Countries that import for personal reasons

Leading purpose for species to be imported:

Now, in terms of importer countries, the top two purposes for import were seen to be for zoos and personal reasons. (Figure 2.6 and Figure 2.7) For personal reasons, we observed that most of the countries in the network with degree centrality were small economic countries like Indonesia, Namibia, Bahrain, and Thailand, to name a few, as most of these countries having low economies tend to have lenient importing trade laws. In fact, CITES has recently called for more protection by strengthening trade laws for southern white rhinos in Namibia, where they live under the severe threat of being killed for their horns [12].

The ripple effects of these loose trade laws can be seen in influential countries in Europe imposing special trade laws on imports from these low-economy countries. For instance, our network noticed that Central Asian and Russian countries like Uzbekistan and Kyrgyzstan are among the top countries importing for personal reasons. Having lenient animal trading law means high chances of low-quality/disease-infected animals being imported into the country. So, recently, avian influenza (bird flu) in Russia led to the EU having special trade law for these Russian countries where you cannot import poultry and poultry products into the UK from non-EU countries, like Russia with an outbreak of avian influenza unless they comply with specific requirements in Commission Regulation (EC) 798/2008 [13].

When analyzing imports for the purpose of zoos, South Africa stands out as South Africa's stronger local currency, making its imports paid for in weaker US dollars relatively less expensive when converted starting from the South African rand. It takes only R380 to import animals for shows, exhibitions, competitions and stud mating or veterinary services [14].

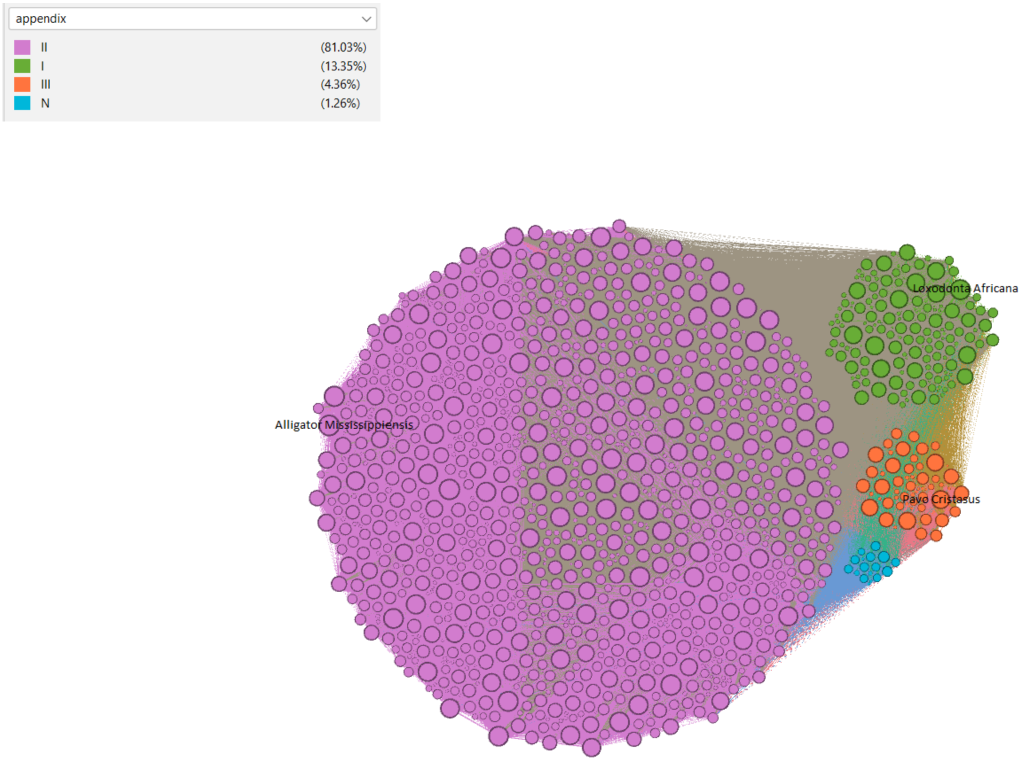


Figure 3.1: Imported taxons categorized through appendix

C. Research Question 3

Which species within each appendix is imported the most?

To try and answer this question, we will use the taxons connected by importing countries' projections to see if any specific nodes stand out in comparison with the others. First, we will visualize the network in its entirety to be able to provide a high-level view of how the taxons are distributed within the different appendices.

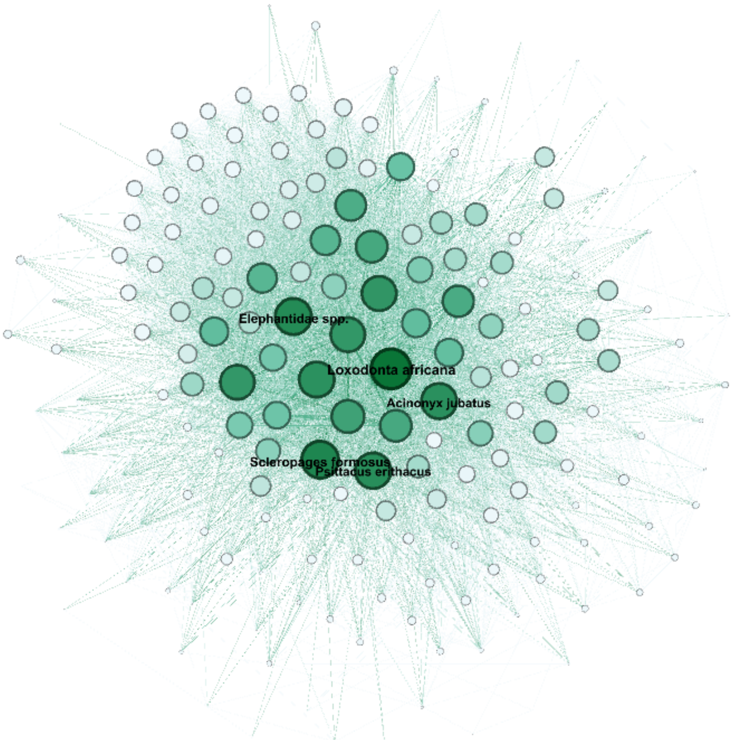
The network above uses “Circle Pack” and “Expansion” layouts that are divided according to their appendix, where the vast majority of the taxons belong to Appendix II. You can also see that there is Appendix N, but we will not analyze them because it is insignificant to our research, as discussed earlier. To identify which taxons have been imported the most, we decided to rank them by degree through their node size. Although this method is not perfect, it does provide a clear enough idea, given the metrics of our projections. Since a taxon is connected if the same country has imported them, a node with a higher degree indicates that if a country has imported some random taxon, there is a high chance that the same country has also imported the specific node. You can see that despite the nodes being ranked through their size, there isn’t a clear stand out in terms of which node has the highest degree. Hence the labeling is necessary to indicate which taxons have the highest. This result highlighted how dense and interconnected the animal trade network is and help explains some of the values we had in our basic statistics section

The node with the highest degree within each appendix are listed below:

- *Appendix I*: Loxodonta Africana - African Bush Elephant
- *Appendix II*: Alligator Mississippiensis - American Alligator
- *Appendix III*: Pavo Cristasus - Indian Peafowl

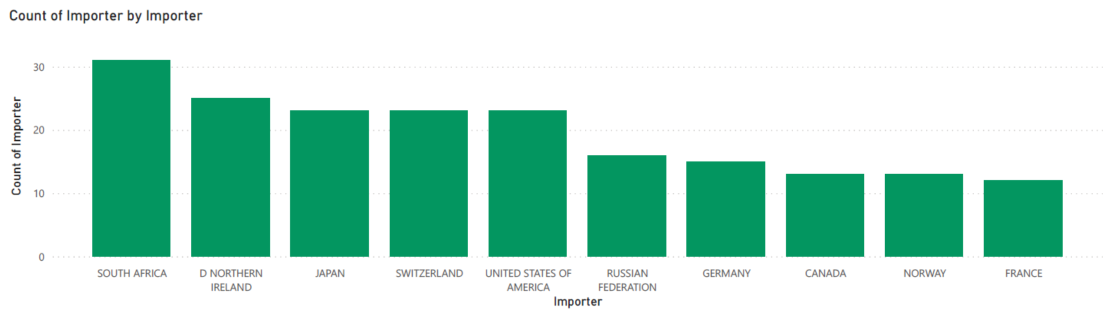
We will now analyze these taxons further to identify the common players and reasons why they are imported. First, we will look at the subset of each appendix individually and look into the node with the top 5 highest degrees to identify any patterns and see how the three taxons above compare with the other highly imported taxons within their appendix.

Appendix I:



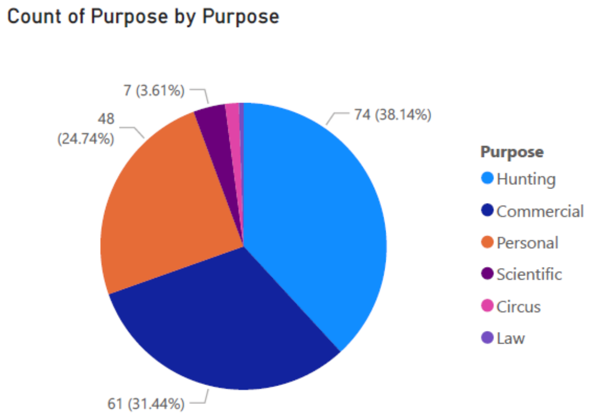
Figures: 3.2: Appendix I taxons sorted through degree and node

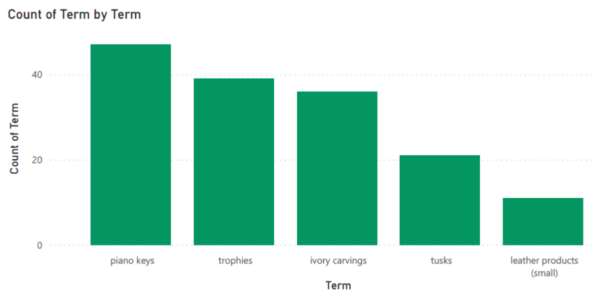
We can observe that the top 5 highest degrees are relatively close in size and colour, which indicates that these animals are also heavily imported. Notice how the Elephantidae spp taxon, a more generic naming classification of elephants, is also in the top 5 highest degrees. We will now use a bar graph to observe which countries import the African elephant the most.



Figures: 3.3: Appendix I taxons top 10 importers by count

The chart above highlights the top 10 importers in the CSV files according to their row count, where we assumed that each row was a single transaction. Although this measure is imperfect, the alternative is to use the quantity column. This method is not preferable because this measure needs to be standardized and varies depending on the type of product that was traded. After identifying the top importers, we proceeded to explore further as to why the African elephants are imported and what kind of product was imported using the graph below





Figures: 3.3: Appendix I taxons classified by purpose. Figures: 3.4: Appendix I taxons ranked by product/term count.

Please note that the term column only shows the top 5 types of products that were imported under the "Loxodonta Africana" taxon for the ten countries that were listed above.

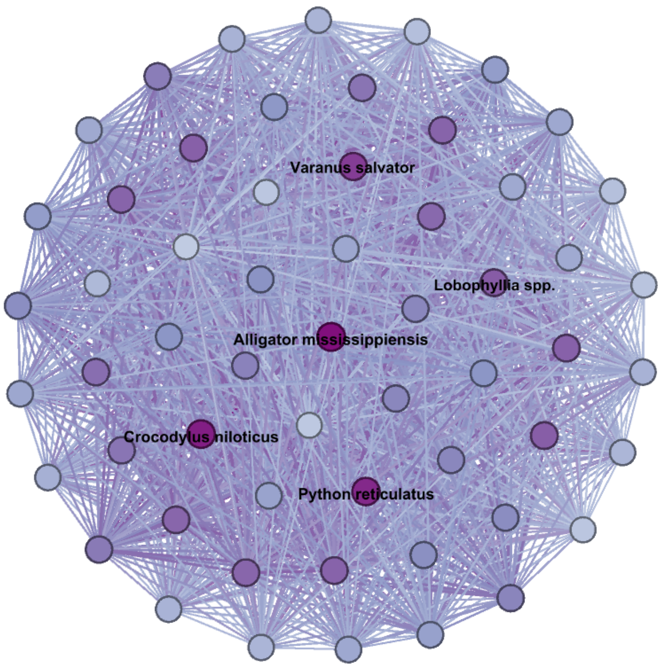
As you can see, *"Hunting," "Commercial,"* and *"Scientific"* dominate a large proportion of the purpose pie chart, with piano keys being the most imported product type. This pie chart raised some confusion because CITES prohibits appendix I taxon from being traded for commercial reasons. However, when you look at the raw data, we noticed that ivory carvings and other body parts were imported for commercial purposes, which led us to believe that this rule only applies to a living appendix I taxon since the only imported African elephants that we could find was traded for a Zoo. We also noticed that "*Trophies*" is just an umbrella term that is all categorized for hunting *"Hunting"* purposes, highlighting their vagueness in the parts of products that were actually imported.

Unfortunately, ivory products and African elephants seem to dominate a large share of this market. The fact that CITES only tracks the legal trade of these animals may imply that the number of all Elephant Products is much higher. The following are statistics that are not specific to the African elephant but showcase the increase in demand for ivory products from the Elephant Trade Information System (ETIS) that keeps track of elephant product seizures.

- As of July 2020, ETIS has over 30,000 seizure records, with almost 28,000 of them being ivory products and the rest non-ivory elephant products
- Despite the commercial ivory trade ban in 1989, the number of seizure cases of ivory products peaked in 2011. It also peaked in total weight seized the following year [5, 6].

We hope that identifying the taxons and importers can help identify the trade patterns and showcase where the demand for such products is centered at.

Appendix II:



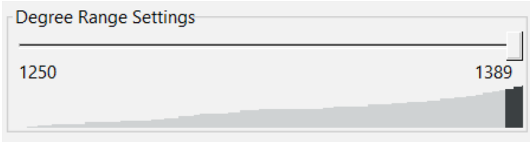
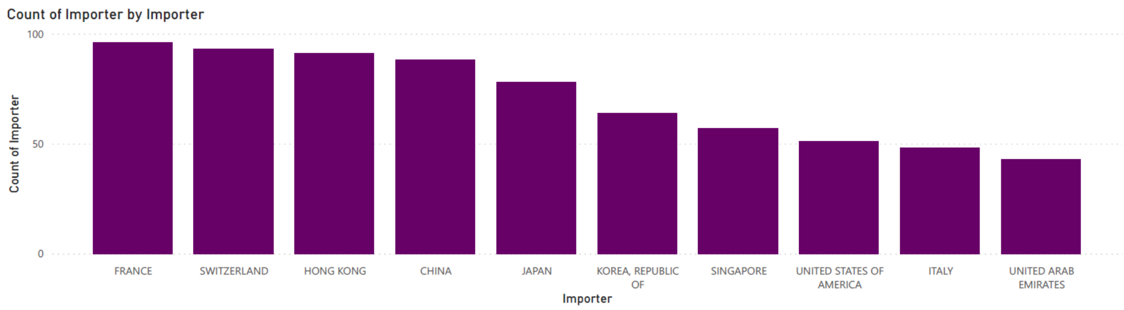


Figure 3.5: Appendix II taxons sorted through degree and node

Given that Appendix II is the densest out of all the appendices, we had to filter out some nodes and edges to be able to make this network visualization more legible. As you can see, even displaying the nodes between 1250-1389 degrees, the edges are still very dense and are relatively close in value in terms of their degree. We can also observe that taxons belonging to the Reptilia class tops this appendix with all four except Lobophyllia spp. (brain coral) having the highest degree in the whole network. We will now use a bar graph to observe which countries import the American alligator the most.



Figures: 3.6: Appendix II taxons top 10 importer count

Here we can see the top 10 importers for the American alligator taxon. The bar chart visualization above and what will be shown below use the same visualization metric as the charts shown in appendix I. We will use the pie charts and bar graphs again to highlight the purpose and types of imported products under this taxon. In terms of the threat of extinction, the American alligator was once federally protected in 1967 due to unregulated hunting for its hide. Fortunately, the population did recover, and by 1987, it was removed from the endangered species list [16].

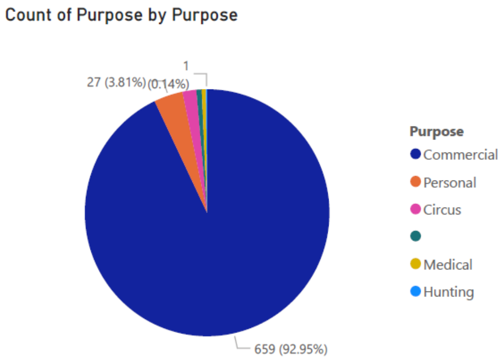


Figure 3.7: Appendix II classified by purpose

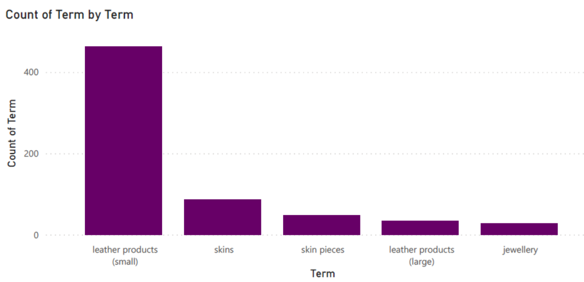


Figure 3.8 Appendix II ranked by term/product count

As you can see from Figure 3.7, the commercial use of American alligator products has the largest proportion in the purpose column by a significant amount. Like the African elephant, we can also observe that the American alligator taxon is generally imported as a product instead of a living organism. We can see from the top 5 products that they heavily revolve around their hide and are all used for commercial purposes, which was the reason they were endangered in the first place. Despite these statistics, the main threat they currently face is habitat loss caused by human infrastructure, resulting in more encounters between the two species [16].

Appendix III:

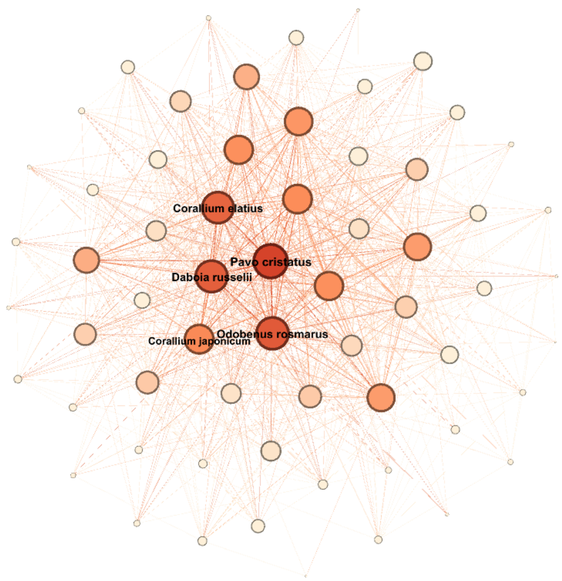
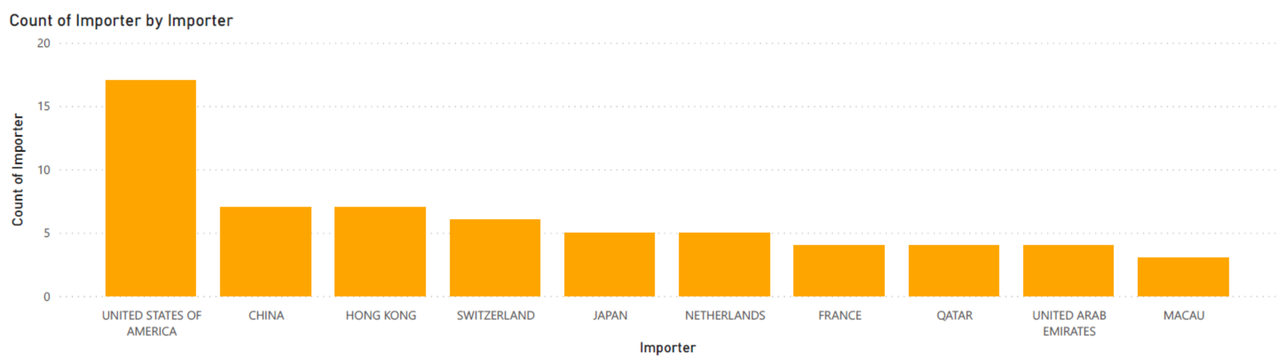


Figure 3.9: Appendix III taxons sorted by degree and node

Figure 3.9 shows that the graph for Appendix III is much sparser than the first 2, with the Indian Peafowl (Pavo Cristatus) having the highest degree. The sparseness may be explained by the conditions of how taxons are categorized into appendix III, as taxons are included at the request of a party that regulates trade in that species and needs the cooperation of other countries to prevent unsustainable trade practices. Since the classification is not as absolute as the other two appendices, it may also be biased towards taxons traded within countries with stricter trading practices. We can also see that the taxons are more random and less related to each other than the other two appendices. We will now create graphs with the same metrics and filters to identify the common countries and the purpose and types of products.



Figures: 3.10: Appendix III taxons top 10 importer count

This bar graph shows the top 10 countries that import Indian Peafowl. We can see that the number is significantly lower than the other two appendices, which could be attributed to the fact that they are not as endangered, so the documentation may not be as enforced as the other two appendices.

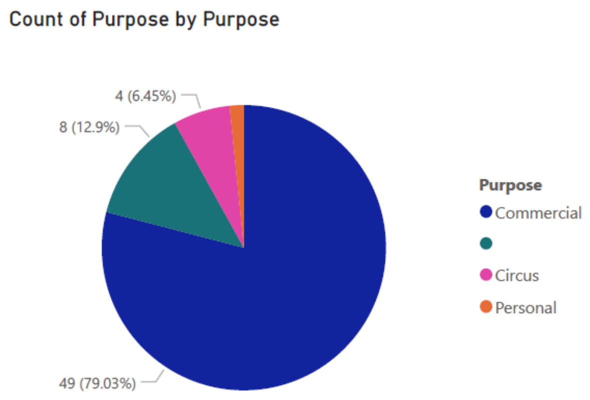


Figure 3.11: Appendix III taxons classified by purpose

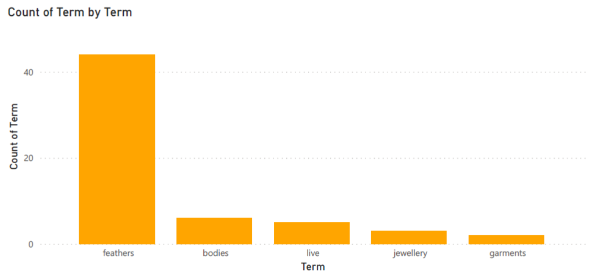


Figure 3.12: Appendix III ranked by term/product count

Like the other two appendices, the purposes of these imports are dominated by commercial use, with 4 out of 5 products being parts of the animal.

In conclusion, the heavily traded taxons in each appendix seem to be traded largely for commercial purposes. We also notice that these taxons are not imported to one specific region or continent, but there is a common thread between all 3 of them in terms of the active contributors from the importer perspective.

Regarding the types of products, it is unfortunate that most of the products that are traded often require the harming or killing of these animals, which highlights the exploitative measure within these trades. Considering that this only accounts for the legal trade only highlights how worrying the actual figures are.

Discussion:

Based on our results, we believe we have accomplished the goals that we set at the beginning of the semester. Within the existing literature surrounding this topic, our paper is aimed to provide a high-level representation of the legal wildlife trade through network science. Though the final paper has limitations, we believe we have adequately answered our research questions and allowed our readers to infer some insightful information. In terms of the knowledge we gained about our network, we identified key taxons and countries in which laws and regulations lead to the increased trade of the particular taxon. Within these taxons, we could identify that commercial reasons were the main driving force for these trades and furthered our knowledge of the trade of endangered species. With these points in mind, we mostly achieved our research goals. Still, we would want to consider the following points to analyze our data better: metadata to make our results richer, alternative visualization methods for deeper analysis and incorporating other components of CITES trade base data in the analysis. In our attempts to answer the research questions, we faced some challenges that limited our analysis, some of which were inherent in the data itself, and some were caused by the approach we chose to take. Although the CITES database is quite organized and extensive, we noticed that its structure and the way it is recorded made it somewhat difficult to analyze them with complete accuracy, especially in a network format. Some of the challenges inherent to the data are outlined below:

- Ambiguity and nuanced data, as seen in research question 3, CITES often categorize some of their data using a singular term. We have also noticed that some taxons are categorized within two appendices depending on certain factors that need more investigation. These nuances would need a more extensive analysis if we were to represent them accurately.
- Incomplete and unstandardized data, in many of the rows, we see a lot of empty columns and discrepancies in the reported trade quantity for both the importers and exporters. We also see products of the same types with differing methods of how they are measured.
- The data does not account for the illegal wildlife trade, which is a significant amount of the whole trading network. This makes the trading data heavily biased towards countries with more open trading activities and extensive documentation. Despite this bias, CITES continues to encourage its members to submit an annual illegal trade report that accounts for seizures of wildlife products [15].

In terms of our approach, we tried to capture the holistic view of the animal networks. Still, we had to make certain decisions which are listed below:

- We used common taxon or common importing/exporting countries as the weights in our network. Though using the reported quantity would have been more ideal, the limitations of the data that was mentioned previously made us opt for this option.

- For network visualization purposes, we assigned a single purpose for each taxon which does not show their other reasons for being traded, hence the usage of PowerBI to provide a more in-depth analysis.
- Using count in our PowerBI and treating a single row as one trade transaction may not accurately depict trade quantity. However, we thought the frequency would at least provide a perspective that can be inferred without extensive data wrangling and standardization techniques.

In future implementations of our analysis, we would like to explore the correlation between origins and countries. (exp/imp), reflecting it on purpose and minimizing the density of the visualizations to create a network which allows us to identify information regarding our network more efficiently.

Methods:

Within each of our projections, the networks were all generated using NetworkX and Gephi. Though the network generations were similar, there are slight changes within the projections where the nodes are the taxons, and the nodes are either importers or exporters to accommodate the slight differences in projections needed.

With the nodes being the taxons, we created nodes for each unique taxon and added attributes that include: Appendix, Class, Order, Family Genus and their purpose for trade. With the edges in this projection, we first deleted all the rows in the data that had the same exporter or importer and taxon to avoid duplicate data and then grouped them by using the taxon and importer/exported to create the combinations of edges within our network.

With the nodes being the importing or exporting country, node and edge generation was similar with changes to the attributes of the nodes. These nodes only contained the list of purposes that the corresponding country had.

To get various basic stats like the number of nodes, edges, and the degree of our network, we used the built-in functions from NetworkX to capture these statistics.To calculate the clustering of the four projections made, the library NetworkX was utilized with the help of the library functions average_clustering and clustering. The connected components were calculated by using number_connected_components. With projections with more than one component, we used connected_components to split the components into a list and then with each list, average_shortest_path_length was called to get the average shortest path for each of the components. If the projection contained only one component, only average_shortest_path_length was called without the need to split the components to get the length.

Each of the projections had null models, which was made by using double_edge_swap to create a new network where the nodes kept the same degree but swapped edges to preserve the degree of each node. Each of these new networks was generated 100 times to create an ensemble of networks to compare our data. The average shortest path length and clustering for these null models were generated using the previously mentioned method.

Most of the code used to capture the network was taken from the lecture with one expectation: we took code from stack overflow to generate edges [18].

For our Gephi network visualization, we used several different layouts and measurements depending on the data we were trying to display. However, some of them are more frequently used than others. For example, degree centrality was heavily used in most of the graphs through their size and colour to highlight a certain node. We considered using betweenness centrality and other variations, but given the context of our data, we thought the interpretation would not make as much sense as degree centrality. In terms of Gephi Layouts, we used the following main layouts:

- Fruchterman Reingold
- ForceAtlas
- Circle Pack
- Circular
- Yifan Hu

The use of the additional layouts listed below helped create changes to fix the positioning and legibility of the elements in the graphs.

- Noverlap
- Label Adjust
- Expansion

As for our PowerBI visualizations, we used the row count as our main measurement to analyze our columns. Though this approach does not encapsulate the actual traded quantity, it shows the trade frequency between two parties and its variables. For the graphs, we simply used bar charts, pie charts, and stacked column charts to infer our measurements as it is intuitive and highlights the differences we wanted to show.

Code:

All code used and created for the project can be found at: https://github.com/VictorTDong/CITES-Network-Analysis

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