Open University of Cyprus

Faculty of Pure and Applied Sciences

Postgraduate (Master's) Programme of Study *Environmental Conservation and Management*

Postgraduate (Master's) Dissertation

Pet Trading of Freshwater Megafauna Species

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Dr. Fengzhi He

May 2023

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Summary

Freshwater ecosystems play a vital role by serving as crucial habitats, maintaining the quality and quantity of water, fostering biodiversity, and providing essential resources and services to human communities. Despite this, the scientific knowledge about megafauna species in freshwater ecosystems is incomplete due to insufficient research and data for more than 35% of the species. The trading of these species has become a major concern in recent years, often involving the capture and trade of threatened or endangered species. It is equally concerning when these species are traded as pets and kept in unsuitable environments. Social media platforms have been recognized as a crucial tool for gaining insights into the extent of this trade, as they provide access to pet owners who display these species online. The creation of a database from information derived from Facebook, Instagram and Twitter profiles, not only reveals pets obtained through the trade but also those captured from the wild. By scrutinizing 372 posts and pictures on some of the most popular social media platforms, gathering information on the 67 species involved was taken place, where freshwater megafauna pets were found, and whether they have been introduced to areas beyond their natural habitat. This information can inform conservation efforts and assist in identifying potential impacts of species invasiveness. Consequently, emphasizing the potential dangers posed by trade and acknowledging its escalating threat becomes crucial in order to raise awareness about the associated risks. However, the use of social media as a source of information also raises ethical concerns, particularly regarding privacy and potential harm to individuals involved in the legal or illegal trade. In summary, social media provides critical information on the pet trade of freshwater megafauna, but it is imperative to use this information ethically and responsibly, with the goal of protecting these vulnerable species.

Keywords: freshwater megafauna, invasiveness, pets, social media, trade.

Περίληψη

Τα οικοσυστήματα του γλυκού νερού διαδραματίζουν ζωτικό ρόλο λειτουργώντας ως ζωτικά ενδιαιτήματα, διατηρώντας την ποιότητα και την ποσότητα του νερού, ενισχύοντας τη βιοποικιλότητα και παρέχοντας βασικούς πόρους και υπηρεσίες στις ανθρώπινες κοινότητες. Παρόλα αυτά, η επιστημονική γνώση για τα είδη μεγαπανίδας στα οικοσυστήματα του γλυκού νερού είναι ελλιπής λόγω ανεπαρκούς έρευνας και δεδομένων για περισσότερο από το 35% των ειδών. Η εμπορία αυτών των ειδών έχει γίνει μια σημαντική ανησυχία τα τελευταία χρόνια, που συχνά περιλαμβάνει τη σύλληψη και το εμπόριο απειλούμενων ή απειλούμενων ειδών. Είναι εξίσου ανησυχητικό όταν αυτά τα είδη διακινούνται ως κατοικίδια και διατηρούνται σε ακατάλληλα περιβάλλοντα. Οι πλατφόρμες μέσων κοινωνικής δικτύωσης έχουν αναγνωριστεί ως ένα κρίσιμο εργαλείο για την απόκτηση γνώσεων σχετικά με την έκταση αυτού του εμπορίου, καθώς παρέχουν πρόσβαση σε ιδιοκτήτες κατοικίδιων ζώων που εμφανίζουν αυτά τα είδη στο διαδίκτυο. Η δημιουργία μιας βάσης δεδομένων από πληροφορίες που προέρχονται από προφίλ στο Facebook, στο Instagram και στο Twitter, όχι μόνο αποκαλύπτει κατοικίδια που αποκτώνται μέσω του εμπορίου αλλά και εκείνα που έχουν αιχμαλωτιστεί από την άγρια φύση. Με τον έλεγχο 372 αναρτήσεων και εικόνων σε μερικές από τις πιο δημοφιλείς πλατφόρμες μέσων κοινωνικής δικτύωσης, πραγματοποιήθηκε συλλογή πληροφοριών για τα 67 είδη που εμπλέκονται, πού βρέθηκαν κατοικίδια μεγαπανίδας γλυκού νερού και εάν έχουν εισαχθεί σε περιοχές πέρα από το φυσικό τους περιβάλλον. Αυτές οι πληροφορίες μπορούν να ενημερώσουν τις προσπάθειες διατήρησης και να βοηθήσουν στον εντοπισμό πιθανών επιπτώσεων της εισβολής ειδών. Ως εκ τούτου, η έμφαση στους πιθανούς κινδύνους που εγκυμονεί το εμπόριο και η αναγνώριση της κλιμακούμενης απειλής του, καθίσταται ζωτικής σημασίας προκειμένου να αυξηθεί η ευαισθητοποίηση σχετικά με τους σχετικούς κινδύνους. Ωστόσο, η χρήση των μέσων κοινωνικής δικτύωσης ως πηγή πληροφοριών εγείρει επίσης ηθικές ανησυχίες, ιδίως όσον αφορά την ιδιωτική ζωή και την πιθανή βλάβη σε άτομα που εμπλέκονται στο νόμιμο ή παράνομο εμπόριο. Συνοπτικά, τα μέσα κοινωνικής δικτύωσης παρέχουν κρίσιμες πληροφορίες για το εμπόριο κατοικίδιων ζώων μεγαπανίδας γλυκού νερού, αλλά είναι επιτακτική ανάγκη να χρησιμοποιηθούν αυτές οι πληροφορίες ηθικά και υπεύθυνα, με στόχο την προστασία αυτών των ευάλωτων ειδών.

Λέξεις-κλειδιά: εισβολή, εμπόριο, κατοικίδια, μεγαπανίδα γλυκού νερού, μέσα κοινωνικής δικτύωσης.

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Chapter 1
Introduction

Freshwater ecosystems are amongst the most diverse ecosystems on the planet. At the same time, they are the source of water, the most essential natural resource, of fundamental interest to humans, animal and plant populations and are completely irreplaceable (He et al., 2019). Despite their importance, they face innumerable and ever-increasing list of threats and pressures, which negatively impact biodiversity and freshwater megafauna species. According to the International Union for Conservation of Nature's Red List of Endangered Species (IUCN, 2022), freshwater vertebrates have declined, with a rate of a decline greater than that of marine or terrestrial ecosystems, with about 30% of megafauna species endangered to extinct.

1.1 Problem description

Humans have a long history of keeping animals as pets, which often function as companions to people (Alves & Rocha, 2018). In addition, people possess pets for aesthetic reasons, or even as an indication of economic or social power due to the diversity, rarity or price of the animals. Among pets the usual or most popular preferences are mammals and birds (Alves & Rocha, 2018). Animals, which may be potential pets, frequently encounter humans accidentally, and some individuals take advantage of this opportunity to capture and keep them (Mitchell, 2009; Warwick & Steedman, 2021). In ancient times, fish which was used as food by the Sumerians, was actual used as pets by the Egyptians and Romans while the Chinese used it for aesthetic reasons (Mitchell, 2009). In the USA, in the late 19th/early 20th century, the collection of ornament fish began by hobbyists (Mitchell, 2009). Animals kept as pets by humans can either come from the local ecosystems or are exotic species that are introduced from another region. Such human-wildlife relationship has also evolved due to globalization. There has been a growing interest in owning exotic animals as pets, leading to global trade in animals. Freshwater animals are widely kept as pets, including fish, amphibians, reptiles, and mammals (Moorhouse et al., 2016). Most of these pet species have small body sizes but it is also not uncommon to have large freshwater animals. Freshwater megafauna is defined as freshwater animals which could reach 30 kg; (He et al., 2017) as pets, such as the Yellow Anaconda (*Eunectes Notaeus*), the Common Hippopotamus (*Hippopotamus amphibius*), the Common Caiman (*Caiman Crocodilus*). According to IUCN Red List database, there is a list of 207 freshwater megafauna species of four taxonomic groups: mammals, fish, reptiles and amphibians (IUCN, 2022).

Fig. 1.1. Examples of freshwater megafauna species. Top picture shows a Siamese Crocodile (*Crocodylus Siamensis),* credits to William Darwall. Middle picture shows Large Hippos (*Hippopotamus amphibious*), credits to Jean-Christophe Viè. Bottom picture shows an Alligator Gar (*Atractosteus spatula),* credits to Zeb Hogan.

In many parts of the world, it is legal to keep this freshwater megafauna as pets. For example, crocodilians, giant turtles and anacondas have been observed in pet-trade market (Sy, 2014). In many parts of the world, it is legal to keep these large freshwater animals as pets, e.g., crocodiles could be owned as pets with licence in Australia (Northern Territory Government Information and Services, 2016). Freshwater megafauna exhibit traits that make them susceptible to extinction, including large body size (Hutchings et al., 2012; Mckinney, 1997). The commercialization of freshwater megafauna as pets could pose risks to their survival through overexploitation. In addition, exotic freshwater megafauna might escape from the confined environment or be released into the wild. Given that freshwater megafauna can modify habitat structure and alter trophic dynamics in local ecosystems, exotic megafauna may pose profound environmental impacts on recipient ecosystems (Frauendorf et al., 2021). The introduction of alien species frequently leads to predatory or competitive effects on the local fauna, thereby impacting native species communities and ecosystem processes (Lockwood et al., 2019).

1.2 Importance and necessity of the study

Freshwater ecosystems face many threats, including habitat fragmentation, climate change, overexploitation, species invasion, pollution and flow modification (Dudgeon et al., 2006; Reid et al., 2019). Hundreds of alien species have been introduced to freshwater ecosystems in Europe as a result of trade in aquariums (Nunes et al., 2015). In India, freshwater species are legally protected from trade, with the sole exception of fish that are traded and exported uncontrollably to other countries, creating potential adverse effects on endemic and rare species(Harrington et al., 2022). In Brazil -regardless of the legal regulation there is a growing use of reptiles as pets (Alves et al., 2019). Currently, over 50% of all assessed freshwater megafauna species are considered as threatened (i.e., listed as Critically Endangered, Endangered, or Vulnerable) on the International Union for Conservation of Nature Red List of Threatened Species (IUCN, 2022; He et al., 2021). Given that many individuals of pets were collected directly from the wild or are offsprings of collected wild individuals, pet trades may become an emerging threat to the survival of many freshwater megafauna species.

1.3 Aims and objectives of the study

Previous studies focusing on freshwater megafauna have mainly investigated on the distributions and population trends of native species and anthropogenic threats to them including overexploitation and dam construction (Geldmann et al., 2014). Although it is documented that many freshwater megafauna species have been traded as pets, to the best of my knowledge, no study has comprehensively investigated the usage of freshwater megafauna as pets at a global scale. This thesis aims to fill in the knowledge gap. Four research questions are embedded in the dissertation:

- Which freshwater megafauna species are usually kept as pets worldwide?
- Where have these species been kept as pets?
- How many megafauna species are exotic species in the region where they have been introduced as pets?
- What are the geographic patterns of the introductions?

These research questions will be answered based on data collected from social media platforms, where a wide range of data can be used to support ecological research and facilitate the development of effective conservation and management strategies (Jarić et al., 2020)

1.4 Clarifications - identification and formulation of main concepts

Freshwater megafauna include all animals that spend a vital part of their life histories in freshwater or brackish ecosystems and can reach a body mass of 30 kg (He et al., 2017). On the one hand, these species are threatened in their native ranges due to their intrinsic traits and multiple threats to them including overexploitation, dam construction, habitat degradation, pollution, species invasion and climate change (He et al., 2017, 2021). On the other hand, freshwater megafauna can profoundly alter local ecosystems when they are introduced to areas outside of their distribution ranges. The hippos and beavers, such as the American beaver, *Castor canadensis* (Nummi & Holopainen, 2014; Wohl, 2015; Wright et al., 2002) which all are very important for the hydrological and biochemical cycles, modify the environment they live in by causing damages on the riversides and build up dams (Bakker et al., 2016). Habitat fragmentation could cause major declines in species, such as the sea-migratory trout, by threatening the pearl mussel populations (Martin Österling & Söderberg, 2015). An exotic pet is a non-native species to the country it resides (Mitchell, 2009). This dissertation uses data from the social media, which nowadays are considered an important part of the daily lives of many people worldwide. The most popular social media are Facebook, Instagram and Twitter, which are internet-based platforms where users can create their own profile/page and present themselves or present their own content of choice (Carrete & Tella, 2008). During the research process of this dissertation 372 posts/pictures were recorded from pet owners, for 67 freshwater megafauna species all over the world.

Chapter 2

Freshwater Ecosystems and Biodiversity

Biodiversity indicates the ensemble of the variety of a biological system, reflecting the diversity of ecological properties (Brumm et al., 2021). This study explores the biodiversity of the freshwater ecosystems, which faces significant challenges due to anthropogenic factors (Collen et al., 2014). According to the IUCN Red List, more than 7,000 freshwater species are under threat globally (IUCN, 2022). Freshwater species are mainly threatened by water pollution, overexploitation and habitat degradation, which affects more than 80% of the threatened species(Collen et al., 2014). In addition, the invasion of exotic species and flow modification of the freshwater biodiversity pose a great risk to the populations of the fauna species (Dudgeon et al., 2006), while lately climate change has been added to the list. Assessing the biodiversity risks of freshwater species and comparing them with smaller species (mammals, reptiles, fish), shows that in some taxonomic groups megafauna are at greater risk (He et al., 2017). The invasion of alien species, encouraged by humans, in areas away from the ones where they come from and inhabit, is spreading speedily around the world at a rapid pace as an inevitable event (Pyšek et al., 2020; Seebens et al., 2017). As previously mentioned, the five categories that pose a threat to freshwater fauna, in conjunction with climate change, also have significant adverse impacts on freshwater biodiversity globally (Dudgeon et al., 2006).

2.1 Freshwater Ecosystems

The scientific community and the production of scientific publications are constantly increasing in number, in contrast to the scale of interest in freshwater ecosystems, which cover mainly developed countries and only two freshwater bodies, rivers and lakes. However, these are not the only freshwater habitats (Faghihinia et al., 2021). As expected, freshwater biodiversity level is much richer in non-glacial regions, compared to the poles and especially in the Antarctic zone, where biodiversity is low and endemic, with a small percentage of invasion (Strayer & Dudgeon, 2010). Slightly less than 70% is covered by ice, and a third of the surface is groundwater, leaving only 0.3% above ground in which aquatic species live. Most of the freshwater water resources are made up of lakes and a quarter are located in the Lake Baikal in Russia (Ikemoto et al., 2004). Rivers host much of the freshwater biodiversity with organisms not found anywhere else, even though they make up 0.0002% of total water on Earth (Dudgeon, 2014).

Although the area covered by freshwater ecosystems is minimal, i.e., 0.8% of the planet's surface, it includes more than 5% of the animal biodiversity (Apostolaki et al., 2020; Dudgeon et al., 2006). In addition to this, inland waters make up 2.5% of the world's water (Apostolaki et al., 2020). Freshwater ecosystems include natural and artificial environments such as rivers, lakes, wetlands, streams, ponds, groundwater, canals, reservoirs, ice caps and drainage ditches (Reid et al., 2020). The biodiversity of freshwater ecosystems provides important goods and services on which the human population relies (Covich et al., 2004). According to the literature, there are three main freshwater bodies: wetlands, rivers/streams and lakes. Wetlands are shallow aquatic environments, with an alternating amount of water during the chronological year, which is why they go through stressful periods (drying). Its hydrology affects plants and microbes and is associated with terrestrial and/or other aquatic ecosystems, thus helping to transfer nutrients from one freshwater system to another. Lakes are also called lentic systems, the hydrology of which is also a key biotic factor, affecting the environment but being influenced by various freshwater bodies. Another important category of freshwater habitats are the lotic ecosystems to which rivers and streams belong and have as their main common feature the one-way flow of water and are categorized by size (Leff, 2019). The formation of rivers and streams is caused by precipitation, creating the natural flow of water, as gravity assists the surface water to get mixed, constantly changing its movement (Balasubramanian, 2005). Organisms that live in these freshwater bodies, could be found only in them (Leff, 2019). Whereas the quantities of available surface water, important for the supply of water resources, are summarized at 0.29%. Groundwater is related to surface water, due to the constant exchange of water and it is also the main provider of used water from the ecosystems on Earth (Apostolaki et al., 2020).

Regarding the limited area of freshwater habitats, one would assume that it is proportional to the number of species that are hosted in them. On the contrary freshwater ecosystems are home to a diverse array of fauna and flora, including numerous species, which makes their high biodiversity particularly intriguing (Dudgeon, 2014). In numbers, this biodiversity reaches 126,000 species, which have been recorded and processed by the scientific community and they occupy 9.5% of the total fauna around the world, thus explaining the disproportion in animal species and the extent of ecosystems (Dudgeon, 2014). The high percentage of freshwater amphibians is also of great interest, accounting for 73% of the total number in all ecosystems. According to this research, many of the species of mammals and amphibians are characterized as endemics, living and developing in a specific area or continent, such as the Amazon which counts 2416 species, 2072 of which are endemic (Balian et al., 2008).

2.1.1 Freshwater habitats and biodiversity

Freshwater ecosystems are mainly categorised into lotic, lentic and underground habitats, where the lotic habitats include the rivers and streams and the lentic habitats include the lakes, wetlands, ponds and swamps (Thorp & Covich, 2001). Freshwater aquatic ecosystems are also known as inland waters, one of which is lakes which may consist of fresh or salt water but do not come into direct contact with marine ecosystems. Although lakes make up only 0.01% of the world's total water, 98% of freshwater on land is due to them. Although freshwater habitats cover only a small portion of the earth's surface, they support a variety of species. The majority of the 126,000 species of freshwater animals are insects (60.4%), 14.5% vertebrates, 10% crustaceans (Balian et al., 2008). Freshwater vertebrates worldwide reach 18,235 species (including freshwater fish) which is the 35% of all vertebrates, while the majority of this percentage is fish and covers 43% of all fish species in the world (Balian et al., 2008).

Because of the distinct lines between water and land or water and air, there is an interaction of natural, biological and chemical processes by conjugating different components of the lakes (Hairston & Fussmann, 2002). As for the rivers, the properties of the streams, the ecology of the fresh waters and their quality consequently influence their direction (Yeakley et al., 2016). Rivers and streams have always served the animals to change their environment and move from one ecosystem to another, either in search of food or to settle in a new area. Due to their special characteristics and their variable nature, they attract many species of animals equally interesting. Since they are not distinguished for their stability, the specific habitats are rich in dissolved oxygen and so the phytoplankton is in abundance together with various nutrients, helping the growth of vegetation, the biomass of which in turn filters them with the effect of as an environment. That is why they are better preserved over time and are determined by their diversity environment (Thorp & Covich, 2001).

Most of the freshwater animal species are fish, however it is important to emphasize the fact that the majority of amphibians, turtles and all categories of crocodiles also belong to them (Dudgeon, 2019). Molluscs, crustaceans, insects, along with mammals, reptiles, amphibians and reptiles cannot be left out (Winemiller, 2017). About 2% of amphibian species go extinct every year from the freshwater ecosystems, a quite high percentage, which indicates a crisis in this taxonomic group. In addition, 72 species of reptiles, 92 birds and 18 species of mammals are also endangered, mainly in the tropics (Dudgeon et al., 2006). Freshwater fish are very diverse and rich in species, and this can be seen from the ancient lakes which support many endemic fish classes, as is the case in the tropics and neotropics, where they are rich in species, but have large numbers of species of fish. In the rivers, on the other hand, live many species of fish such as migratory salmon and sturgeon, while the Eurasian humpback often with human intervention seems to be introduced to other areas from where it comes from. Biodiversity seems to be affected, however, by climate and habitat productivity, and therefore species richness tends to be found in the more tropical regions (Winemiller, 2017). The highest diversity of freshwater species is found in the Amazon Basin, with Brazil as the dominant country holding over 12% of the total (Collen et al., 2014). The US, Colombia and China have about 10% of all the freshwater species and Indo-Malay region is the richest area on terms of taxa proportion (Collen et al., 2014). It should be noted that there is a great lack of information about freshwater species mainly in Central and South America, which does not facilitate their research. In particular, and with regard to the species of freshwater megafauna, the largest numbers of species are found in South America, the central region of the African continent, and South and Southeast Asia (Carrizo et al., 2017).

2.1.2 Importance of freshwater ecosystems

The significant benefits and services that freshwater ecosystems provide to human communities and the natural environment are based on the functions of their bodies and their diversity (Faghihinia et al., 2021). The growth of an area, demographically, industrially and economically, implies the reduction of water, the most basic natural resource for humans. This interest leads the most developed countries to turn to other regions, to ensure this supply (Faghihinia et al., 2021). Population expansion and increasing demand for water and energy, which began to be identified after the 18th century, affect the quality and quantity of services provided by freshwater ecosystems. Water is an important factor in the development of tourism and recreational activities (e.g., rafting, kayaking, hiking, sports activities) in areas located near lakes or rivers (Aylward, 2005). Water supply used for drinking, cooking, washing, industrial uses and aquaculture are some of the most important services offered by the freshwater habitats (Aylward, 2005). The Millennium Assessment has categorised the benefits that the people receive from the ecosystems into provisioning, regulating, cultural and supporting (Millennium Ecosystem Assessment (Program), 2005).

In general, humans are directly dependent on lentic ecosystems with which they maintain a long-term relationship in relation to drinking water supply, irrigation, recreation, aesthetics and other human activities that can only be characterized as harmful to the environment (Hairston & Fussmann, 2002).

As a result, the impact on the health of communities without direct access to drinking water is evident, highlighting how the water scarcity crisis affects the standard of living for these populations (Dudgeon, 2014). The health of a lotic or lentic aquatic ecosystem is a crucial prerequisite for ensuring the availability of clean freshwater that all organisms require. Therefore, it is essential to maintain all the services that the ecosystem is capable of providing (Petersen et al., 2019). In addition, the plants, trees, and phytoplankton of the ecosystems contribute to the enhancement of living conditions for populations, as they are characterized by a diverse and valuable flora. For hundreds of years humans have taken advantage of rivers and lakes by using drinking water, or water in agriculture, energy production and hydropower, pharmaceuticals, biofuel, cultural values, harvesting plants, fish and other species for consumption or exploitation, transportation, industrial purposes (Apostolaki et al., 2020; Strayer & Dudgeon, 2010).

Like other freshwater habitats, wetlands are also rich in fauna and flora, which also belong to the food chains of humans and animals. In addition, their presence in nature reduces floodwaters, traps carbon and helps in plant regeneration. Wetlands are then very important in soil hydration and its fertilisation, as sediments contain nutrients, oxygen and microbial organisms whose functions contribute to the use of wetlands as water sources (Leff, 2019). Moreover, there is a category of needs that are covered by freshwater ecosystems, without them deviating from their natural space and without human intervention. Some of them concern entertainment and recreational factors from which no person is exempt, mainly in rich areas, by contrast to poorer countries that show more interest in the flood control services which can also benefit due to the freshwater ecosystems (Aylward, 2005).

Rivers therefore host a magnitude of large or tiny animals in size, the latter play a key role in the food chains of freshwater ecosystems as their functions include feeding, collecting and grazing. In addition to the animals that live in the habitat, there are also animals-visitors from neighbouring or remote areas who receive the benefits such as food consumption, drinking water, protection

from the weather (sun, rain) or even temporarily relocation. Waste is produced by all species, which feed on other animals, creating a healthy and vital life cycle of the natural environment. Streams, on the other hand, rely on this type of food recycling without adversely affecting living beings, which indisputably receive direct and indirect influence. Vegetation of trees and shrubs in lotic habitats in addition to promoting shading in animals, absorb pollutants from human activities and extract traces of metal from sediments (Balasubramanian, 2005.; Yeakley et al., 2016).
Worldwide 86% of the available water is used in the irrigation of fields and in all the processes that follow the agricultural production and most of it is covered by the underground aquifers. In addition, groundwater controls the flow of freshwater into rivers and streams to prevent drought during harmful months. Wetlands also serve water purification and erosion processes, while operating as carbon sequestration facilities, bringing climate change under control. Certainly, the most important service they provide is the biodiversity of rare and endangered species as well as migratory birds (Apostolaki et al., 2020).
Furthermore, the contribution approach not only considers the services provided by nature but also links nature with people, highlighting the importance of culture and creating three categories of contributions: material, non-material, and regulatory (Díaz et al., 2018; Nicolás Ruiz et al., 2021). In this case, the material contribution of nature to the people is the goods that are being consumed or used, such as the water irrigation for drinking, cooking, washing and other uses, the fish and other species for food or as ornaments, raw materials, renewable energy, hydropower, biofuel and transport. The non-material consist of aesthetic and recreational purposes, tourism activities, water sports and fishing. The regulating NCP's (Nature's Contributions to People) are the regulation of the freshwater quantity and quality, regulation of climate, regulation of detrimental organisms that cause alterations in the ecosystem, regulation of air quality, soil formation (including erosion control), regulation of hazard events (i.e. flood) and habitat creation.

2.2 Threats to freshwater biodiversity

2.2.1 Persistent threats

In the early 2000s, studies have indicated that the decline in biodiversity is more severe in freshwater ecosystems compared to terrestrial or marine ecosystems (Turak et al., 2017). Freshwater ecosystems are continuously exposed to various stressors such as overexploitation, water pollution, habitat degradation, flow modification, species invasion, and climate change (Dudgeon et al., 2006; Winemiller, 2017).

Freshwater aquatic ecosystems are facing a range of pressures that differ from the past, including human-induced habitat degradation and climate change, as well as flow modification, invasive species, increased nutrient levels, and water extraction (Faghihinia et al., 2021; Millennium Ecosystem Assessment (Program), 2005). Habitat degradation has both direct and indirect impacts on the freshwater ecosystem, including its fauna and surrounding communities, by increasing the risk of communicable diseases (Dudgeon et al., 2006). Species that are more reliant on freshwater habitats are particularly vulnerable to local threats and dangers (Collen et al., 2014).

Freshwater animal species are confined to specific areas due to natural or human-made barriers, such as mountains and dams, which restrict their range and limit their ability to adapt to varying climatic and ecological conditions. As a result, freshwater fauna has a greater risk of biodiversity loss compared to species in other ecosystems that are more adaptable (Dudgeon, 2014).

The global demand for water has led to an increase in the construction of dams to meet human needs, resulting in significant impacts on freshwater species, their habitats, and nutrient transport (Vörösmarty et al., 2010). Alterations in flow caused by dams can disrupt aquatic environments and species productivity, especially for fish (Rytwinski et al., 2017). However, the construction of dams can change the physical structure of freshwater ecosystems, threatening their biodiversity by restricting the spatial movement of species, particularly migratory animals and plants (Dudgeon et al., 2006). In Brazil, research has shown that freshwater flow is crucial at the mouth of a river, and dam construction has led to flow modifications that negatively affect biodiversity (Polli et al., 2021). Overall, the construction of dams is a major threat to freshwater habitats and their species, as it causes habitat loss and deteriorates flow conditions (Winemiller, 2017).

Human activities that exploit water resources, such as irrigation, have led to a reduction in the quantity of water available. These activities also contribute to water pollution, further reducing the quality of the water resource (Vörösmarty et al., 2010). In addition, the production of energy can lead to thermal pollution. Throughout history, the drainage, extraction, and impoundment of water bodies have been recognized as negative human impacts on water resources. These impacts have been exacerbated by the expansion of agriculture and industry, which have led to land degradation, water shortages, and the fragmentation of inland water systems (Petersen et al., 2019).

The utilization of reptiles and mammals, particularly freshwater turtles and crocodiles, for their meat and skin, is a concern associated with human intervention (Winemiller, 2017). In terms of fish species, the catch rate has increased fourfold in the last 70 years, and China is responsible for a quarter of the global catch from inland ecosystems (David Allan et al., 2005). There is no indication of an increase in the availability of aquatic species for fishing, as historical evidence points to the tremendous pressure from overexploitation of freshwater fauna (David Allan et al., 2005).

Freshwater ecosystems are impacted by various factors, with man-made changes to wetlands being one of them. Such changes can lead to the creation of new wetlands to replace lost functions (Sun et al., 2021). Water pollution is a major issue caused solely by human activities, and it can have devastating effects on freshwater species (Sun et al., 2021). The problem of pollution has intensified with the rise of industrial development, leading to the influx of nutrients that contaminate water bodies (Smith, 2003). Urbanization in countries such as India and China is also causing destruction to areas surrounding rivers and streams, as sand is used for concrete (Dudgeon et al., 2006). In the face of global air pollution, freshwater ecosystems are no longer considered a commodity. The species that survive in these ecosystems are typically the most resistant to pollution, especially in underdeveloped countries where high concentrations of pollutants, metals, and low dissolved oxygen levels due to agriculture, livestock, and industrial waste are common (Vörösmarty et al., 2010).

The presence of exotic species in freshwater ecosystems can have negative impacts on native species by accelerating their adaptation to the new environment. Human activities have facilitated the introduction and spread of invasive species, leading to changes in the composition of aquatic fauna and affecting the biodiversity of indigenous species. The loss of habitats and the effects of climate change further facilitate the spread of these exotic species (Winemiller, 2017). The introduction of non-native plants can also compete with endemic species and modify soil nutrient dynamics, as they may have different properties and physiological characteristics. For example, the bacterium *Cylindrospermopsis raciborskii* is a non-native species that can cause disruption and introduce invasive algae, leading to problems in aquatic ecosystems (Leff, 2019). Insects can also reduce the availability of food for other animals and transmit pathogenic microorganisms, posing a threat to native species (Dudgeon, 2014).

2.2.2 Emerging threats

Apart from the persistent threats mentioned above, the emerging threats are causing damages by alternating the freshwater biodiversity. These are consisted by: the changing climates, e-commerce and invasions, infectious diseases, harmful algal blooms, expanding hydropower, emerging contaminants, engineered nanomaterials, microplastic pollution, light and noise, freshwater salinisation, declining calcium, cumulative stressors (Reid et al., 2019).

The impact of human-induced climate change on freshwater species is severe, as they struggle to adapt to new environments and relocate to suitable habitats that may not exist. This puts them at risk of extinction, as our understanding of their requirements in new locations is limited (Dudgeon, 2019; Leff, 2019). Anthropogenic stressors, combined with climate change, place a significant burden on freshwater ecosystems, affecting biodiversity and water quality (Millennium Ecosystem Assessment, 2005). Although measures have been taken to optimize aquatic environments and preserve biodiversity, the situation remains grim (Acero Triana et al., 2021). Changes in temperature, rainfall, and weather patterns impact freshwater biodiversity, altering the distribution and metabolism of aquatic organisms and reducing dissolved oxygen levels in warmer waters (Winemiller, 2017). This prompts the flora to consume more water, exacerbating freshwater scarcity, and increasing the need for water pumping. Human adaptation to new climatic conditions involves building more dams, levees, and water diversions to protect against flooding, which creates further pressure on freshwater systems (Dudgeon, 2014). According to a North American study, climate change has caused reductions in fish populations through species interactions and genetic changes (Lynch et al., 2016).

E-commerce plays a crucial role in the trade of freshwater flora and fauna, but this practice poses a threat to the biosecurity of species and increases the likelihood of introducing invasive and non-native species, causing problems for native ones (Reid et al., 2019).

The potential transmission of diseases through contaminated freshwater is a cause for concern, as it can lead to severe consequences for human societies, as has been seen with diseases such as typhoid fever or cholera in the past. Tropical countries are particularly susceptible to bacterial diseases transmitted through freshwater ecosystems, which account for a significant proportion of all diseases (Dudgeon et al., 2006). As mentioned earlier, habitat degradation and microplastic pollution also contribute to the emergence of infectious diseases (Dudgeon, 2014; Reid et al., 2019).

Yeakley et al. (2016) noted that some modifications in freshwater ecosystems may provide temporary benefits to the biota but can ultimately compromise the quality of ecosystem services. The appearance of harmful algae, for example, can cause significant changes in biodiversity and fauna mortality due to changes in water quality and physiological alterations in the habitat environment (Reid et al., 2019).

Hydropower is a renewable energy source that has the potential to improve freshwater defence against various threats, but it also contributes to climate change and requires the construction of dams, which can have negative impacts on freshwater ecosystems (Reid et al., 2019; Vörösmarty et al., 2010).

Mining works produces discharges of emerging contaminants that have a devastating effect on the oxidation of iron and sulphur, which lowers the pH by having a negative impact on the entire life of the lotic ecosystem (Leff, 2019; Reid et al., 2019).

The disposal of microplastics into freshwater ecosystems, including streams, urban sewage, and faecal effluent, is a human-made threat that affects water quality and promotes the spread of pathogenic diseases. The chlorination process used to treat water can also produce trichloromethane, which is harmful to freshwater (Leff, 2019). Microplastics pose a risk to aquatic fauna if ingested, endangering their lives (Reid et al., 2019). Furthermore, engineered nanomaterials, primarily found in industrial, clinical, and pharmaceutical waste, can have long-lasting negative effects on the plants and animals of freshwater ecosystems exposed to high concentrations of toxic chemicals in their habitat (Reid et al., 2019). The artificial light and noise that is produced via the urbanisation and industrialisation of the areas surrounding or close to rivers and lakes, could also disturb and pollute the fauna species of the freshwaters, whether they are endangered or not (Reid et al., 2019). The salinisation of the freshwater links to the reduction of the species number, reproduction and quality of life and the declining calcium percentage causes shifts in the lake vertebrate assemblages and is possible to affect the food webs (Reid et al., 2019). Cumulative stressors resulting from human activities and the impacts of climate change also play a significant role in freshwater ecosystem degradation (Reid et al., 2019). According to research conducted in the Mediterranean area, 89% of all the freshwater species has been affected (Clavero et al., 2010).

2.3 Freshwater megafauna

There are many shortcomings in the scientific research community regarding the knowledge of the freshwater megafauna, as well as the lack of an official definition. Most of the papers are, until now, focusing on megafauna species of terrestrial and marine ecosystems. Consequently, the freshwater megafauna animals are excluded from the scientific interest. Large-bodied animals have been distinguished from the rest of the species in terrestrial and marine ecosystems based on a threshold of their weights (Estes et al., 2016; Ripple et al., 2019). The same distinction was suggested for the freshwater ecosystems with an application of a 30kg weight threshold (He et al., 2018). In this dissertation, all species over 30 kg in size that have lived a respectable part of their life cycle in freshwater or brackish ecosystems, and may be fish, reptiles, mammals, or amphibian species, are considered as freshwater megafauna (He et al., 2017). Freshwater ecosystems are constantly affected by many anthropogenic factors, and accordingly the megafauna, from which many species that are considered endangered and threatened are affected (IUCN, 2022). Freshwater megafauna species, are also considered umbrella species, since their conservation could indirectly protect other species in their habitat raising environmental awareness (He et al., 2017). Certainly, the pressures on freshwater megafauna cannot be quantified accurately due to insufficient information and data. As research has shown that megafauna mammals are in greater risk to threats and extinction than smaller sized mammals (Ripple et al., 2016). Therefore, their vulnerability rate is higher due to the small number of individuals and because many of them are k-strategist animals and are not reproduced as much and as often as the other species (Cardillo et al., 2005). A freshwater large-bodied fish is the European sturgeon *Acipenser sturio* is found very often in Europe and its population is under great decrease (Williot et al., 2008). There are in total 22 megafauna species that are habitats of European freshwater ecosystems namely: *Silurus glanis*, *Pusa caspica*, *Huso huso*, *Esox Lucius*, *Acipenser stellatus*, *Acipenser persicus*, *Acipenser nudiventris*, *Acipenser gueldenstaedtii*, *Lota lota*, *Cyprinus carpio*, *Hucho taimen*, *Castor fiber*, *Salmo trutta*, *Salmo salar*, *Stenodus nelma*, *Pusa hispida saimensis*, *Pusa hispida ladogensis*, *Megalops atlanticus*, *Acipenser sturio*, *Hucho hucho*, *Salmo marmoratus*, *Trionyx triunguis* (IUCN, 2022).

2.3.1 Diversity patterns of freshwater megafauna

There is not much information or data collected concerning the distribution ranges of the freshwater megafauna in an extended geographical part, globally. According to faunal classification specifications of freshwater species, 207 megafauna species of freshwater ecosystems were collected (Carrizo et al., 2017; He et al., 2017). The majority consists of 130 species of fish. Reptiles come second with 44 species, then mammals with 31 species and finally 2 amphibian species (Table 2.1).

Table 2.1. List of the total number of freshwater megafauna species (IUCN, 2022).

Taxa	Common_name_comment	Taxon
Andrias davidianus	Chinese Giant Salamander	Amphibian
Andrias japonicus	Japanese Giant Salamander	Amphibian
Aaptosyax grypus	Mekong giant salmon carp	Fish
Acipenser baerii	Siberian sturgeon	Fish
Acipenser dabryanus	Yangtze Sturgeon, River Sturgeon, Dabry's Sturgeon	Fish
Acipenser fulvescens	Lake Sturgeon	Fish
Acipenser gueldenstaedtii	Russian sturgeon	Fish
Acipenser medirostris	Green Sturgeon	Fish
Acipenser mikadoi	Sakhalin Sturgeon	Fish
Acipenser naccarii	Adriatic Sturgeon, Italian Sturgeon	Fish
Acipenser nudiventris	Ship Sturgeon, Spiny Sturgeon	Fish
Acipenser oxyrinchus	Gulf Sturgeon	Fish
Acipenser persicus	Persian Sturgeon	Fish
Acipenser schrenckii	Amur Sturgeon	Fish
Acipenser sinensis	Chinese Sturgeon	Fish
Acipenser stellatus	Stellate Sturgeon, Sevruga, Star Sturgeon	Fish
Acipenser sturio	Common Sturgeon, Atlantic Sturgeon, Baltic Sturgeon, German Sturgeon	Fish
Acipenser transmontanus	White Sturgeon	Fish
Anguilla reinhardtii	Speckled longfin eel	Fish
Arapaima agassizii		Fish
Arapaima gigas	Arapaima, Pirarucu	Fish
Arapaima leptosoma		Fish
Arapaima mapae		Fish
Arius gigas	Giant Sea Catfish	Fish
Aspiorhynchus laticeps	Big head schizothracin	Fish
Atractosteus spatula	Alligator gar	Fish
Bagarius yarrelli	Giant devil catfish	Fish
Bagrus docmak	Sudan catfish	Fish
Barbus grypus	Shabout	Fish
Bathyclarias worthingtoni		Fish
Brachyplatystoma capapretum		Fish
Brachyplatystoma filamentosum	Kumakuma	Fish
Brachyplatystoma rousseauxii	Gilded catfish	Fish
Carcharhinus leucas	Bull Shark	Fish
Catla catla	Catla	Fish
Catlocarpio siamensis	Giant Carp, Giant Barb	Fish
Channa marulius	Great snakehead	Fish
Chrysichthys cranchii	Kokuni, Kokuni (FB), Manora	Fish
Chrysichthys grandis	Kukumai	Fish

Clarias gariepinus	African Catfish, Sharptooth Catfish, Catfish, Common Catfish, Mudfish, Barbel, Sharptoothed Catfish	Fish
Clarias macrocephalus	Broadhead Catfish	Fish
Colossoma macropomum	Cachama	Fish
Ctenopharyngodon idella	Grass Carp	Fish
Cyprinus carpio	Wild Common Carp	Fish
Electrophorus electricus	Electric eel	Fish
Eleutheronema tetradactylum	Fourfinger threadfin	Fish
Elopichthys bambusa	Yellowcheek	Fish
Esox lucius	Northern Pike	Fish
Esox masquinongy	Muskellunge	Fish
Glyphis gangeticus	Ganges Shark	Fish
Glyphis garricki	New Guinea River Shark, Northern River Shark	Fish
Glyphis glyphis	Speartooth Shark	Fish
Hemibagrus maydelli	Krishna Mystus	Fish
Hemibagrus microphthalmus	Irrawaddy Mystus	Fish
Hemibagrus wyckioides	Asian Red Tailed Catfish, Red fin bagrus	Fish
Heterobranchus bidorsalis	African catfish	Fish
Heterobranchus longifilis	Catfish, Sampa, Vundu, Vundu (FB)	Fish
Himantura dalyensis	Freshwater Whipray	Fish
Hoplias aimara	Anjumara, wolf fish	Fish
Hucho hucho	Danube Salmon, Huchen	Fish
Hucho taimen	Siberian Taimen, Mongolian Taimen, Siberian Salmon, Taimen	Fish
Huso dauricus	Kaluga	Fish
Huso huso	Beluga, Giant Sturgeon, European Sturgeon, Great Sturgeon	Fish
Hydrocynus goliath	Giant tigerfish, Giant tigerfish	Fish
Hypophthalmichthys molitrix	Silver Carp	Fish
Hypophthalmichthys nobilis	Bighead Carp	Fish
Hypselobarbus mussullah	Mussullah barb	Fish
Ictalurus furcatus	Blue Catfish	Fish
Ictiobus bubalus	Smallmouth buffalo	Fish
Ictiobus cyprinellus	Bigmouth Buffalo	Fish
Labeo rohita	Rohu	Fish
Lates angustifrons	Tanganyika Lates	Fish
Lates calcarifer	Barramundi	Fish
Lates japonicus	Japanese lates	Fish
Lates niloticus	Nile Perch, Victoria Perch, African Snook	Fish
Lepisosteus osseus	Longnose Gar	Fish
Lota lota	Burbot	Fish
Luciobarbus esocinus	Pike Barbel	Fish
Luciocyprinus striolatus	Striped Pikecarp	Fish
Maccullochella ikei	Eastern freshwater cod	Fish

Maccullochella mariensis	Mary River Cod	Fish
Maccullochella peelii	Murray Cod, Murray River Cod	Fish
Megalops atlanticus	Tarpon	Fish
Morone saxatilis	Striped Bass	Fish
Mylopharyngodon piceus	Black carp	Fish
Myxocyprinus asiaticus	Chinese sucker	Fish
Neoceratodus forsteri	Australian lungfish	Fish
Oncorhynchus tshawytscha	Chinook Salmon	Fish
Pangasianodon gigas	Mekong Giant Catfish, Giant Catfish	Fish
Pangasianodon hypophthalmus	Striped catfish	Fish
Pangasius pangasius	Pangas catfish	Fish
Pangasius sanitwongsei	Giant Pangasius, Paroon Shark, Pangasid-catfish, Pla Thepa	Fish
Parahucho perryi	Sakhalin Taimen, Ito, Japanese Huchen, Sea-run Taimen	Fish
Paratrygon ajereba	Manzana Ray, Ceja Ray	Fish
Phractocephalus hemioliopterus	Redtail catfish	Fish
Polydactylus macrochir	Grand Threadfin	Fish
Polyodon spathula	Paddlefish, Spadefish, Duckbill Cat, Spoonbill Cat	Fish
Potamotrygon brachyura	Short-tailed river stingray	Fish
Potamotrygon motoro	Ocellate River Stingray	Fish
Pristis pristis	Largetooth Sawfish	Fish
Probarbus jullieni	Jullien's Golden Carp, Seven-striped Barb	Fish
Probarbus labeamajor	Thicklipped Barb	Fish
Protopterus aethiopicus	Marbled lungfish	Fish
Psephurus gladius	Chinese Paddlefish, Chinese Swordfish, White Sturgeon	Fish
Pseudoplatystoma corruscans	Spotted sorubim	Fish
Pseudoplatystoma fasciatum	Barred sorubim	Fish
Ptychocheilus lucius	Colorado Pikeminnow, Colorado Squawfish, Colorado Squafish, Colorado River Squawfish	Fish
Pylodictis olivaris	Flathead Catfish	Fish
Rita sacerdotum	Salween rita	Fish
Salminus brasiliensis	Dorado	Fish
Salmo marmoratus	Marble trout	Fish
Salmo salar	Atlantic Salmon, Black Salmon	Fish
Salmo trutta	Brown Trout, Sea Trout	Fish
Salvelinus namaycush	Lake trout	Fish
Scaphirhynchus albus	Pallid Sturgeon	Fish
Sciades couma	Couma sea catfish	Fish
Scomberomorus sinensis	Chinese Seerfish	Fish
Silurus asotus	Amur catfish	Fish
Silurus glanis	Wels Catfish	Fish
Silurus soldatovi	Soldatov's catfish	Fish

Silurus meridionalis	Chinese large-mouth catfish	Fish
Sorubimichthys planiceps	Firewood catfish	Fish
Stenodus nelma		Fish
Tor putitora	Putitor Mahseer, Golden Mahaseer	Fish
Tor tor	Tor barb	Fish
Urogymnus polylepis	Giant freshwater stingray	Fish
Urogymnus ukpam	Pincushion Ray,Thorny Freshwater Stingray	Fish
Wallago attu	Wallago	Fish
Wallago leerii	Helicopter Catfish?	Fish
Wallago micropogon		Fish
Zungaro jahu	Manguruyu	Fish
Zungaro zungaro	Guilded Catfish	Fish
Aonyx capensis	African Clawless Otter, Cape Clawless Otter	Mammal
Aonyx congicus	Congo Clawless Otter, Zaire Clawless Otter, Small-clawed Otter, Small-toothed Clawless Otter, Cameroon Clawless Otter	Mammal
Blastocerus dichotomus	Marsh Deer	Mammal
Bubalus arnee	Wild Water Buffalo	Mammal
Castor canadensis	American Beaver	Mammal
Castor fiber	Eurasian Beaver	Mammal
Choeropsis liberiensis	Pygmy Hippopotamus	Mammal
Hippopotamus amphibius	Hippopotamus, Hippo	Mammal
Hydrochoerus hydrochaeris	Capybara	Mammal
Inia araguaiaensis	Araguaian boto	Mammal
Inia boliviensis	Bolivian river dolphin	Mammal
Inia geoffrensis	Amazon River Dolphin	Mammal
Kobus leche	Southern Lechwe	Mammal
Kobus megaceros	Nile Lechwe	Mammal
Lipotes vexillifer	Baji, Yangtze River Dolphin	Mammal
Neophocaena asiaeorientalis ssp. asiaeorientalis	Yangtze Finless Porpoise	Mammal
Orcaella brevirostris	Irrawaddy Dolphin, Snubfin Dolphin	Mammal
Phoca vitulina ssp. mellonae	Ungava Seal	Mammal
Platanista gangetica ssp. gangetica	Ganges River Dolphin	Mammal
Platanista gangetica ssp. minor	Indus River Dolphin	Mammal
Pteronura brasiliensis	Giant otter, Giant Brazilian otter	Mammal
Pusa caspica	Caspian Seal	Mammal
Pusa hispida ssp. ladogensis	Ladoga Seal	Mammal
Pusa hispida ssp. saimensis	Saimaa ringed seal	Mammal
Pusa sibirica	Baikal Seal	Mammal
Sotalia fluviatilis	Tucuxi	Mammal
Tapirus bairdii	Baird's Tapir, Central American Tapir	Mammal
Tragelaphus spekii	Sitatunga, Marshbuck	Mammal

Trichechus inunguis	Amazonian Manatee, South American Manatee	Mammal
Trichechus manatus	American Manatee, West Indian Manatee	Mammal
Trichechus senegalensis	African Manatee, West African Manatee	Mammal
Alligator mississippiensis	American Alligator, Mississippi Alligator	Reptile
Alligator sinensis	Chinese Alligator	Reptile
Amyda cartilaginea	Asiatic Softshell Turtle, Southeast Asian Softshell Turtle	Reptile
Apalone ferox	Florida Softshell Turtle	Reptile
Caiman crocodilus	Common Caiman, Spectacled Caiman	Reptile
Caiman latirostris	Broad-snouted Caiman	Reptile
Caiman yacare	Yacaré	Reptile
Chitra chitra	Southeast Asian Narrow-headed Softshell Turtle	Reptile
Chitra indica	Indian Narrow-headed Softshell Turtle	Reptile
Chitra vandijki	Burmese Narrow-Headed Softshell Turtle	Reptile
Crocodylus acutus	American Crocodile	Reptile
Crocodylus intermedius	Orinoco Crocodile	Reptile
Crocodylus johnsoni	Australian Freshwater Crocodile	Reptile
Crocodylus mindorensis	Philippines Crocodile	Reptile
Crocodylus moreletii	Morelet's Crocodile, Belize Crocodile	Reptile
Crocodylus niloticus	Nile Crocodile	Reptile
Crocodylus novaeguineae	New Guinea Crocodile	Reptile
Crocodylus palustris	Mugger	Reptile
Crocodylus porosus	Salt water Crocodile	Reptile
Crocodylus rhombifer	Cuban Crocodile	Reptile
Crocodylus siamensis	Siamese Crocodile	Reptile
Eunectes beniensis	Bolivian anaconda, Beni anaconda	Reptile
Eunectes deschauenseei	Dark Spotted Anaconda	Reptile
Eunectes murinus	Anaconda	Reptile
Eunectes notaeus	Yellow Anaconda	Reptile
Gavialis gangeticus	Gharial	Reptile
Macrochelys temminckii	Alligator Snapping Turtle	Reptile
Mecistops cataphractus	African Slender-snouted Crocodile	Reptile
Melanosuchus niger	Black Caiman	Reptile
Nilssonia gangetica	Indian Softshell Turtle	Reptile
Nilssonia leithii	Leith's Softshell Turtle	Reptile
Nilssonia nigricans	Black Soft-shell Turtle, Black Softshell Turtle	Reptile
Orlitia borneensis	Bornean River Turtle, Malaysian Giant Turtle	Reptile
Osteolaemus osborni	Congo Dwarf crocodile	Reptile
Osteolaemus tetraspis	African Dwarf Crocodile, West African Dwarf Crocodile	Reptile

Paleosuchus palpebrosus	Dwarf Caiman	Reptile
Paleosuchus trigonatus	Smooth-fronted Caiman	Reptile
Pelochelys bibroni	Asian Giant Softshell Turtle, Southern New Guinea giant softshell turtle	Reptile
Pelochelys cantorii	Cantor's Giant Softshell, Frog-faced Softshell Turtle	Reptile
Pelochelys signifera	Northern New Guinea Giant Softshell Turtle	Reptile
Podocnemis expansa	South American River Turtle, Arrau turtle	Reptile
Rafetus swinhoei	Yangtze Giant Softshell Turtle	Reptile
Tomistoma schlegelii	False Gharial	Reptile
Trionyx triunguis	African Softshell Turtle	Reptile

They inhabit freshwater habitats all over the world apart from Antarctica. The main continents that freshwater megafauna is found are: South America, Central Africa and South and Southeast Asia (Carrizo et al., 2017). Although South America is home to many species of megafauna, most of them are not endangered species (Carrizo et al., 2017). However, the same does not apply to South and Southeast Asia, where many more threatened species seem to live than in other regions (Carrizo et al., 2017). The 22 species that are found in the European freshwater habitats are consisted by 17 fish species, 4 mammals and 1 reptile. There are no large-bodied amphibians that live in European freshwater habitats (IUCN, 2022). The four mammals present in Europe consist of three seal species (*Pusa caspica, Pusa hispida saimensis, Pusa, hispida ladogensis*) and the Eurasian beaver *Castor Fiber,* while the only reptile found is the African softshell turtle *Trionyx triunguis* (Table 2.2).

Table2.2. Freshwater megafauna species that currently occur in Europe (He et al., 2018).

Taxa	Common name	Taxon	Class
Acipenser gueldenstaedtii	Russian sturgeon	Fish	Actinopterygii
Acipenser nudiventris	Ship Sturgeon, Spiny Sturgeon	Fish	Actinopterygii
Acipenser persicus	Persian Sturgeon	Fish	Actinopterygii
Acipenser stellatus	Stellate Sturgeon, Sevruga, Star Sturgeon	Fish	Actinopterygii
Acipenser sturio	Common Sturgeon, Atlantic Sturgeon, Baltic Sturgeon, German Sturgeon	Fish	Actinopterygii
Cyprinus carpio	Wild Common Carp	Fish	Actinopterygii
Esox lucius	Northern Pike	Fish	Actinopterygii
Hucho hucho	Danube Salmon, Huchen	Fish	Actinopterygii
Hucho taimen	Siberian Taimen, Mongolian Taimen, Siberian Salmon, Taimen	Fish	Actinopterygii
Huso huso	Beluga, Giant Sturgeon, European Sturgeon, Great Sturgeon	Fish	Actinopterygii
Lota lota	Burbot	Fish	Actinopterygii
Megalops atlanticus	Tarpon	Fish	Actinopterygii
Salmo marmoratus	Marble trout	Fish	Actinopterygii
Salmo salar	Atlantic Salmon, Black Salmon	Fish	Actinopterygii
Salmo trutta	Brown Trout, Sea Trout	Fish	Actinopterygii
Silurus glanis	Wels Catfish	Fish	Actinopterygii
Stenodus nelma		Fish	Actinopterygii
Pusa caspica	Caspian Seal	Mammal	Mammalia
Castor fiber	Eurasian Beaver	Mammal	Mammalia
Pusa hispida saimensis	Saima ringed Seal	Mammal	Mammalia
Pusa hispida ladogensis		Mammal	Mammalia
Trionyx triunguis	African Softshell Turtle	Reptile	Reptilia

The continent where most freshwater megafauna species reside is Asia, with 77 species and the least enriched is Australia with just 18 species (Fig. 2.1).

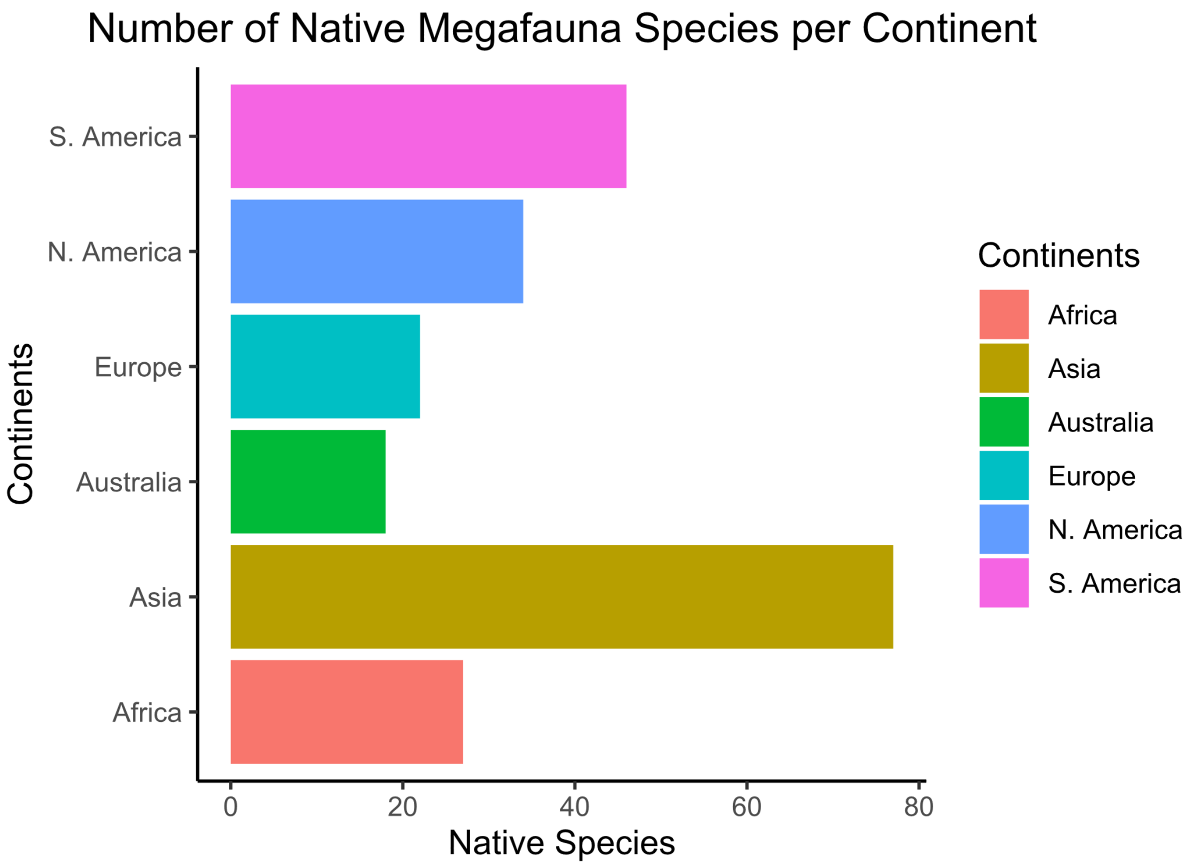

Fig. 2.1. The global distribution of native freshwater megafauna, categorised in continents (He et al., 2019).

Worldwide, the biggest percentage of all the freshwater megafauna species are habitats of the five largest hydrobasins, meaning the rivers by diversity order: Amazon with 35 species, Congo (23), Orinoco (23), Mekong (22), and Ganges-Brahmaputra (22) (He et al., 2018).

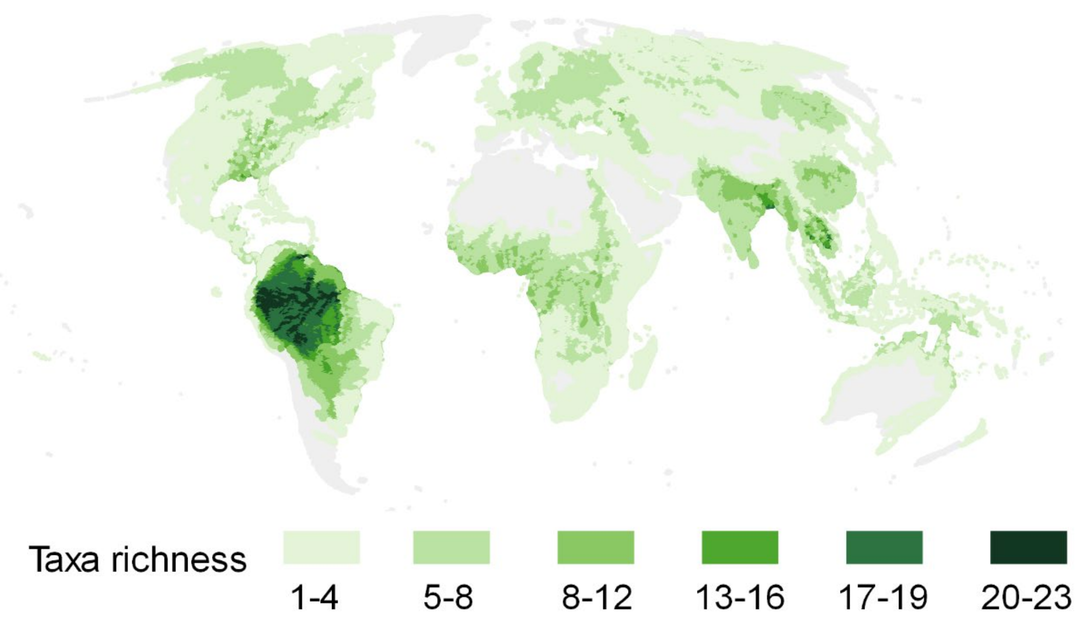

Fig. 2.2. Global distributions of freshwater megafauna species (modified from He et al., 2018).

As shown in the Fig. 2.1 the distribution of the freshwater megafauna species is extended around the regions of the most important rivers. Amazon basin, as shown in the map, is the richest region of all in freshwater taxa and it is located in South America, likewise is Orinoco river that comes second in species richness. There is an, as well, significant number of taxa on the East and Southeast Asia and that is explained by the location of Mekong river that runs through 6 countries in that area. The last interesting area which is coloured dark green in a map is the area where the Ganges-Brahmaputra delta lies mainly located in India and Bangladesh. Similarly, West and Central Africa areas and some parts of North America and Europe are coloured by lighter green shades, since these regions host less species.

2.3.2 Threats to freshwater megafauna

In general, there is not much information in the scientific literature or that has been researched worldwide on the change in the numbers of large species of animals in fresh water. Of course, it has been documented that the decline of freshwater megafauna species (88%) is more than double the decline of terrestrial (38%) and marine (36%) vertebrates (McRae et al., 2017). Therefore, the species for which there is not a satisfying amount of data are also the ones that suffer the greatest reduction in their populations.

Many freshwater megafauna species are victims of poaching in various countries around the world (He et al., 2017). A significant increase in the aquaculture of freshwater species during recent years at a rate of 9.2% over the last 50 years compared to other ecosystems is a result of human population increase and therefore their demand for food (Millennium Ecosystem Assessment (Program), 2005). The ever-increasing interest in aquaculture jeopardises the health of freshwater ecosystems, and therefore, of fauna and megafauna, such as carp grown in ponds. Another typical example would be the sturgeons and paddlefish that have been a key part of the overexploitation cycle for years, for the sake of the black caviar trade internationally (Pikitch et al., 2005). Subsidies and a lack of fisheries restriction or regulation policy make the fish vulnerable to overexploitation (Mora et al., 2009).

The main threats to freshwater megafauna are the same as those to the biodiversity of freshwater ecosystems and involve overexploitation, dam construction, habitat degradation, pollution, climate change and invasive species. Due to these factors (indiscriminate or in combination with each other), in addition to other freshwater fauna, the freshwater megafauna species are negatively affected. The extinction of megafauna, populations are greatly decreasing, the rate of death and reproduction as well as their quality of life are a direct consequence of the risks. Humans often pose a challenge to freshwater ecosystems by introducing invasive exotic species, which can create significant issues for these ecosystems (e.g., lakes) and by cultivating non-native species (Abell, 2002). When one of the strongest causes of the endangered freshwater fishes is invasive species, then the ecosystem is at greater risk (Clavero et al., 2010).

More specifically and according to the International Union for Conservation of Nature there are particular causes of the threats that each megafauna species faces (IUCN, 2022). The main threats include: transportation and service corridors (shipping lanes), residential and commercial development(housing and urban areas, commercial and industrial areas, tourism and recreational areas), energy production and mining (oil and gas drilling), biological resource use (fishing and harvesting aquatic resources), human intrusions and disturbance (recreational, work and other activities), natural system modifications (other ecosystem modifications), invasive and other problematic species, genes and diseases (invasive, non-native/alien species diseases),pollution (industrial and military effluents, agricultural and forestry effluents, excess energy), climate change and severe weather (habitat shifting and alteration) and other unspecified reasons (IUCN, 2022). The European megafauna species are also suffering from the same dangers as shown on the Red List of IUCN but unfortunately there is not enough information about three species which belong to the fish taxon and they are the: *Esox Lucius*, *Lota lota* and *Salmo salar* (IUCN, 2022). It is important to see the Graph 2.2 which shows the threats on the European freshwater megafauna according to the IUCN categorisation (Graph 2.2).

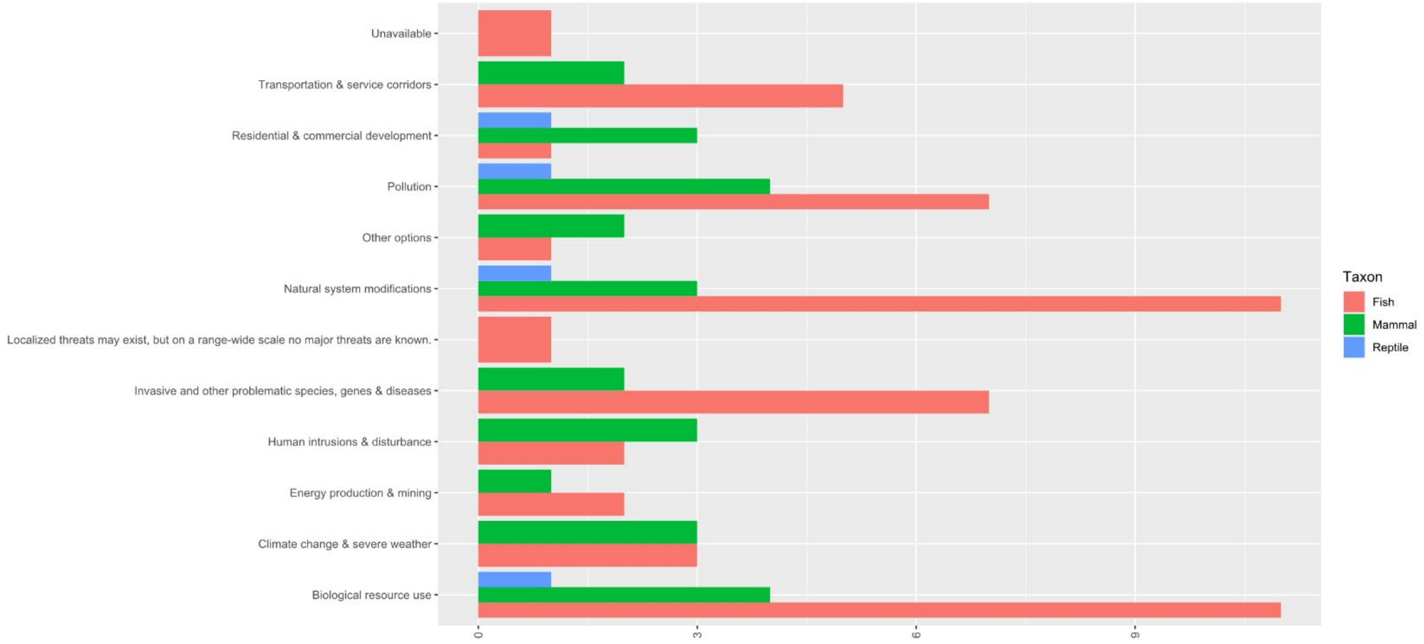

Fig. 2.3. Threats of freshwater megafauna according to the IUCN Red List (IUCN,2022).

2.3.3 Conservation status of freshwater megafauna

The term conservation status of the species has been inspired by the IUCN through the Red List, indicating their vulnerability and the threats they are facing (Gonzalez-Suarez et al., 2012; Murray et al., 2014). The IUCN is the International Union for Conservation of Nature that aims to protect the environment and through research and evaluation provides the scientific community with the Red List of threatened species, including the freshwater species at European and international level (IUCN, 2022). There are nine conservation status categories according to the: Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW) and Extinct (EX). 95 species were recently assessed (less than 10 years ago). More than 35% of the freshwater megafauna is insufficiently or out-of-date assessed with no assessment at all or with last assessment longer than 10 years ago (Fig. 2.4).

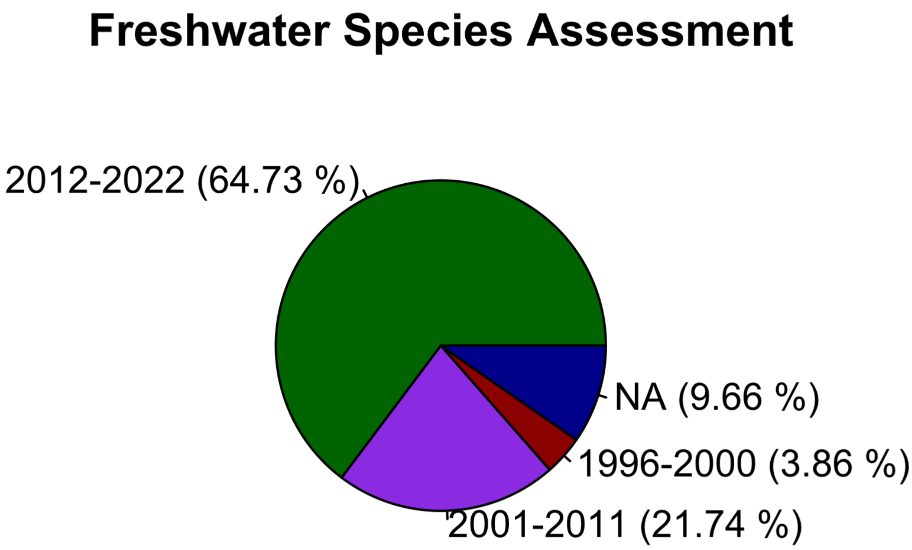

Fig. 2.4. The last time period when freshwater megafauna species were assessed starting from 1996 until 2022, including a category with insufficient assessment, unassessed or having lack of information about them (NA) until today (IUCN, 2022).

Most of the megafauna is part of the Least Concern group by occupying 1/3 of the total number (Table 2.3).

Table 2.3. Freshwater megafauna species that are of Least Concern and not threatened according to the Red List, per species name and categorised by taxonomic group (IUCN, 2022).

Binomial Name	Common Name	Taxon	Red List category (2022-8)
Anguilla reinhardtii	Speckled longfin eel	Fish	LC
Atractosteus spatula	Alligator gar	Fish	LC
Bagrus docmak	Sudan catfish	Fish	LC
Bathyclarias worthingtoni		Fish	LC
Brachyplatystoma rousseauxii	Gilded catfish	Fish	LC
Catla catla	Catla	Fish	LC
Channa marulius	Great snakehead	Fish	LC
Chrysichthys cranchii	Kokuni, Kokuni (FB), Manora	Fish	LC
Chrysichthys grandis	Kukumai	Fish	LC
Clarias gariepinus	African Catfish, Sharptooth Catfish, Catfish, Common Catfish, Mudfish, Barbel, Sharptoothed Catfish	Fish	LC
Ctenopharyngodon idella	Grass Carp	Fish	LC
Electrophorus electricus	Electric eel	Fish	LC
Elopichthys bambusa	Yellowcheek	Fish	LC
Esox lucius	Northern Pike	Fish	LC
Esox masquinongy	Muskellunge	Fish	LC
Hemibagrus maydelli	Krishna Mystus	Fish	LC
Hemibagrus microphthalmus	Irrawaddy Mystus	Fish	LC
Hemibagrus wyckioides	Asian Red Tailed Catfish, Red fin bagrus	Fish	LC
Heterobranchus bidorsalis	African catfish	Fish	LC
Heterobranchus longifilis	Catfish, Sampa, Vundu, Vundu (FB)	Fish	LC
Himantura dalyensis	Freshwater Whipray	Fish	LC
Hydrocynus goliath	Giant tigerfish, Giant tigerfish	Fish	LC
Ictalurus furcatus	Blue Catfish	Fish	LC
Ictiobus bubalus	Smallmouth buffalo	Fish	LC
Ictiobus cyprinellus	Bigmouth Buffalo	Fish	LC
Labeo rohita	Rohu	Fish	LC
Lates calcarifer	Barramundi	Fish	LC
Lates niloticus	Nile Perch, Victoria Perch, African Snook	Fish	LC
Lepisosteus osseus	Longnose Gar	Fish	LC
Lota lota	Burbot	Fish	LC
Maccullochella peelii	Murray Cod, Murray River Cod	Fish	LC
Morone saxatilis	Striped Bass	Fish	LC
Mylopharyngodon piceus	Black carp	Fish	LC
Pangasius pangasius	Pangas catfish	Fish	LC
Protopterus aethiopicus	Marbled lungfish	Fish	LC
Pylodictis olivaris	Flathead Catfish	Fish	LC
Rita sacerdotum	Salween rita	Fish	LC
Salmo marmoratus	Marble trout	Fish	LC
Salmo salar	Atlantic Salmon, Black Salmon	Fish	LC
Salmo trutta	Brown Trout, Sea Trout	Fish	LC
Sciades couma	Couma sea catfish	Fish	LC

Silurus asotus	Amur catfish	Fish	LC
Silurus glanis	Wels Catfish	Fish	LC
Silurus soldatovi	Soldatov's catfish	Fish	LC
Silurus meridionalis	Chinese large-mouth catfish	Fish	LC
Stenodus nelma		Fish	LC
Wallago leerii	Helicopter Catfish	Fish	LC
Zungaro zungaro	Guilded Catfish	Fish	LC
Castor canadensis	American Beaver	Mammal	LC
Castor fiber	Eurasian Beaver	Mammal	LC
Hydrochoerus hydrochaeris	Capybara	Mammal	LC
Pusa sibirica	Baikal Seal	Mammal	LC
Tragelaphus spekii	Sitatunga, Marshbuck	Mammal	LC
Alligator mississippiensis	American Alligator, Mississippi Alligator	Reptile	LC
Apalone ferox	Florida Softshell Turtle	Reptile	LC
Caiman crocodilus	Common Caiman, Spectacled Caiman	Reptile	LC
Caiman latirostris	Broad-snouted Caiman	Reptile	LC
Caiman yacare	Yacaré	Reptile	LC
Crocodylus johnsoni	Australian Freshwater Crocodile	Reptile	LC
Crocodylus moreletii	Morelet's Crocodile, Belize Crocodile	Reptile	LC
Crocodylus niloticus	Nile Crocodile	Reptile	LC
Crocodylus novaeguineae	New Guinea Crocodile	Reptile	LC
Crocodylus porosus	Salt water Crocodile	Reptile	LC
Eunectes beniensis	Bolivian anaconda, Beni anaconda	Reptile	LC
Eunectes deschauenseei	Dark Spotted Anaconda	Reptile	LC
Eunectes murinus	Anaconda	Reptile	LC
Eunectes notaeus	Yellow Anaconda	Reptile	LC
Paleosuchus palpebrosus	Dwarf Caiman	Reptile	LC
Paleosuchus trigonatus	Smooth-fronted Caiman	Reptile	LC

The last 6 categories, mentioned before, are the ones indicating which species are under the greatest risk compared to the rest and are considerably threatened because they show the level of exposure of the freshwater megafauna diversity in their indigenous ecosystems. An almost equal percentage is held by 3 categories of threatened species (CR, EN and VU) which consists of almost 50%, while 33% of the megafauna species are in the Least Concern group. Furthermore, the IUCN has yet to evaluate only 8% of the megafauna species, and only one species, the Chinese paddlefish *Psephurus gladius*, has been classified as Extinct in the Wild, indicating that it can no longer be found as a resident in its natural habitat and may only exist in captivity or outside its native range (IUCN, 2022).

In addition, each taxonomic group has unique implications regarding their categorization as threatened or with data deficiency, with particular interest given to the fish taxon which boasts the highest number of taxa. The freshwater megafauna fish include the only species that is extinct (*Psephurus gladius*) and the only species which is Extinct in the Wild (*Acipenser dabryanus*). Reptiles as the second richest taxonomic group have the majority of its species in the category of critically endangered but with no species on the data deficiency and that could mean a potential interest of the scientific world in large-bodied reptiles, such as crocodiles. Moreover, the majority of the threatened mammals of interest are part of the endangered species and the only two amphibian species (*Andrias davidianus, Andrias japonicus*) are endangered or vulnerable. The Figure 2.5 presents a direct comparison of the conservation status in each taxon (Fig. 2.5).

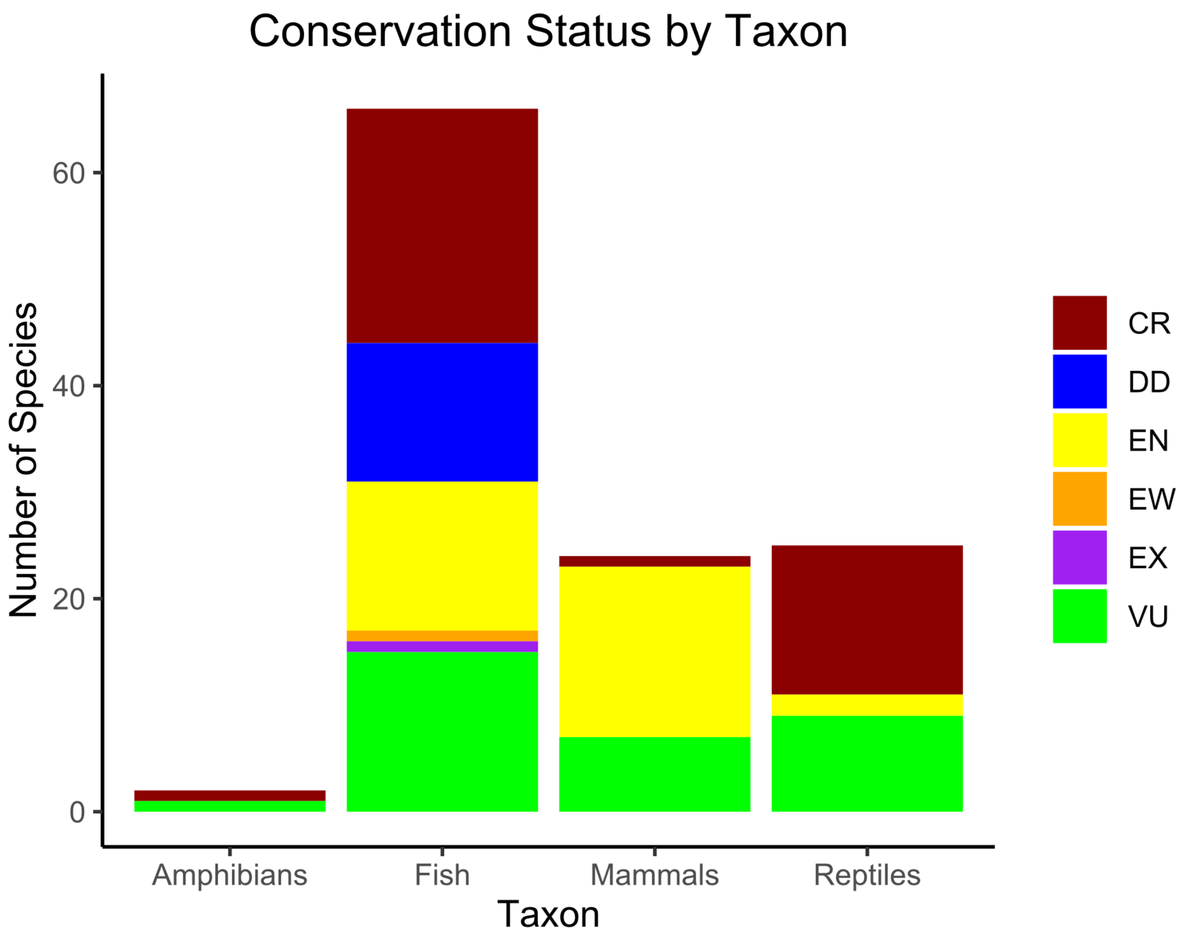

Fig. 2.5. Conservation status per taxonomical category (IUCN, 2022).

In total for 29 species there is lack of information and data or they were not evaluated, while 35% of all the taxon are of low risk (IUCN, 2022). It is also interesting to observe the population trend of each species. The majority of the species are suffering from a decline in their population the last years which makes them more vulnerable overtime (Fig. 2.6).

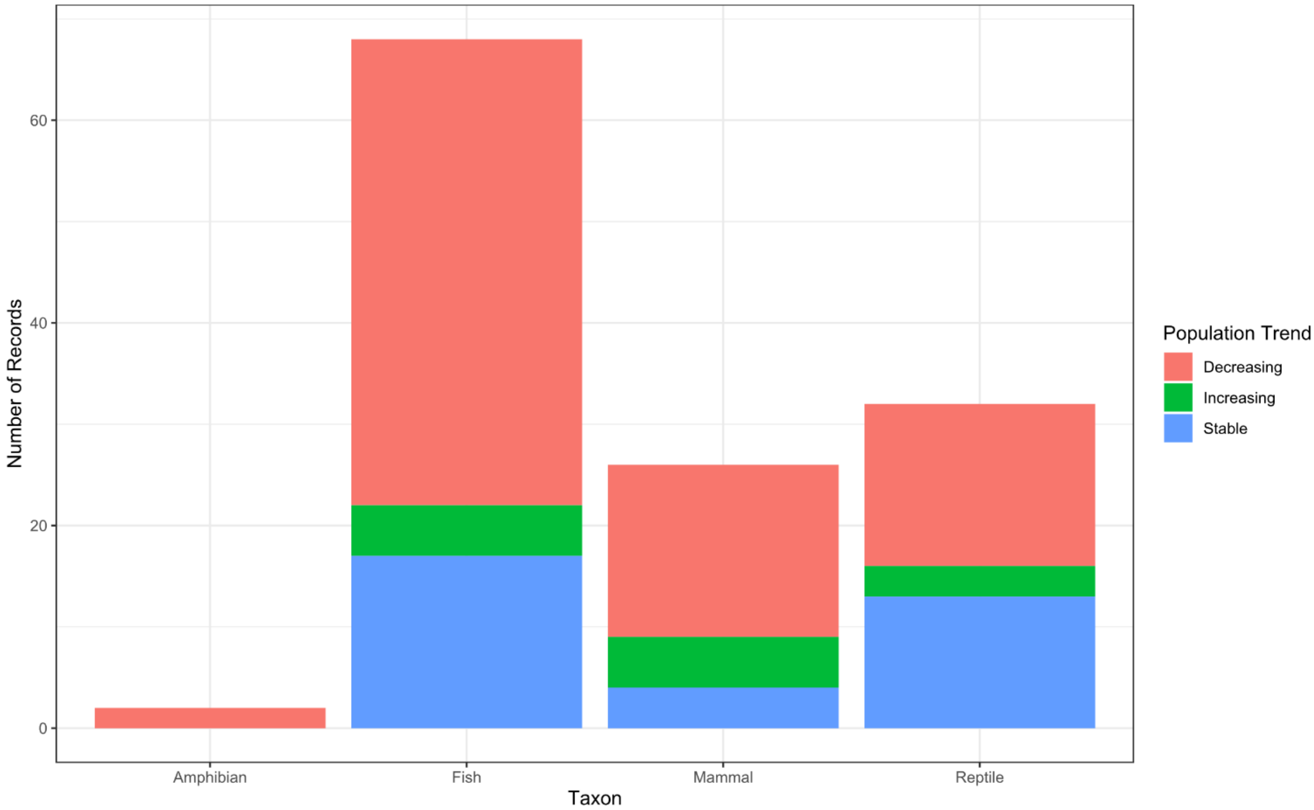

Fig. 2.6. The population trend of all the freshwater megafauna species according to their taxonomic group and records (IUCN, 2022).

In Fig. 2.6 it is shown that for 79 species there is not enough information about their population trend, it is unknown, unspecified or not available. The population of 33 species is stable and 13 species have an increase in their populations, only 5 of them are fish while the rest are reptiles and mammals. As mentioned before, megafauna has bigger rate of extinction than smaller sized species in specific taxonomic groups and more than 80% of the freshwater megafauna distribution ranges that have been collected, do not belong to protected areas (He et al., 2018).

There is a small number of research which has been conducted for some freshwater megafauna taxa and only on a few species (i.e., paddlefish, sturgeons). However not all taxonomic groups of freshwater megafauna have been recorded, therefore there is an absence of an overview of the risks faced by these species.

The species for which there is a greater lack of data, or the scientists have not focused their interest as much as it would be necessary are fish (which also make up the majority of megafauna species) and reptiles (Ford, Cooke, Goheen, & Young, 2017). A particularly large gap of information regarding the current conservation status is found in more than 45 species mainly in South America (He et al., 2018).

Human pressures on important freshwater watersheds seem to be decreasing in intensity with many being protected such as the Amazon river. However, is not the case for megafauna species for which unfortunately there is not much evidence, and this reduces their value in terms of the threats they face from pollution originating from human activities (agriculture, mining, oil spills) (Abell et al., 2017).

According to CITES, 94 species of freshwater megafauna belong to the endangered species and despite this they face problems of overexploitation to be used in food or medicine (Da Nóbrega Alves et al., 2008) as are several species of freshwater megafauna turtles (Sze & Dudgeon, 2006) as well as large fish (i.e. Arapaima) (Castello et al., 2013). Although, recently CITES published new results which include 8 additional species threatened (CITES, 2022). The construction of dams also has the power to change megafauna populations to a considerable extent, as there are many changes in the conditions (as mentioned in a previous chapter) of the environment in which they live, feed and reproduce, such as the catfish (Hogan, 2011).

It was also calculated what is the proportion of the threatened freshwater megafauna species by excluding the categories of Least Concern and Near Threatened and by subtracting the categories to which species are part of and there is no sufficient data or none at all. Almost half of the threatened species are fish, second threatened group are reptiles with 25% and third are the mammals with 21% (Table 2.4).

Table 2.4. Proportion of threatened freshwater megafauna according to the IUCN categories and by following the calculation: % threatened = (Critically Endangered + Endangered + Vulnerable) / (total assessed - Extinct - Extinct in the Wild - Data Deficient).

Taxon	CR	EW	EN	VU	DD	EX	Threatened %
Fish	22	1	14	15	13	1	5
Mammals	1	0	16	7	0	0	21
Reptiles	14	0	2	9	0	0	25
Amphibians	1	0	0	1	0	0	2

2.4 Pet trade

As mentioned before, the Convention on International Trade in Endangered Species of wild fauna and flora (CITES, 2022) creates a worldwide mechanism on the regulation of animal and plant trade (De Klemm, 1993). Many countries around the world are members of CITES, however, some of them have not enacted the corresponding national laws on foreign trade to be adapted or even approved by CITES (De Klemm, 1993). Animal or plant species that have either escaped from their natural environment where their populations live or have been released into a new environment are considered naturalized species (Gherardi, 2007). The naturalization process is achieved when species are intentionally or by accident introduced by humans and they overcome obstacles related to the location, environment and reproduction (Richardson et al., 2000; Toukhsati, 2017). The invasion of exotic species into new areas and away from their native range does not always require introduction by humans but can also be achieved naturally (Richardson et al., 2000). It has been shown that alien species could be identified by detecting environmental DNA that inhabit places other than their native ones (Keskin, 2014). Non-native alien species is one of the greatest threats to biodiversity and it is a matter of great interest for the ecology (Toukhsati, 2017). Invasive species create the possibility of replacing lost legacies of native animals with an upward trend of modern legacies, as for example happens very often in freshwater fauna where it is more intense than in other ecosystems (Frauendorf et al., 2021). People and animals have built a strong, trusted situation and an intimacy throughout the years, therefore a lot of animals have been part of the human culture (Franklin, 1999). Animals have been domesticated and used as pets for different kinds of reasons, such as for companion, entertainment, therapy, hunting or aesthetic reasons (Alves & Rocha, 2018). When an animal is non-native for an ecosystem and is also non-domesticated is it considered to be an exotic pet (Warwick et al., 2018). Nowadays it is conventional and quite common to own an exotic species as a pet but many times it is difficult to have it registered and this causes issues in the identification of the exact number of the domesticated animals which are brought from other continents (Mitchell, 2009).

2.4.1 Pet trade of wild animals

In modern times, just like in antiquity, human societies have incorporated, additional members in their society, which are called pets, that are admittedly considered common and ordinary, as well as animals beyond the normal range, such as freshwater angelfish (Mitchell, 2009). A lot of exotic and non-exotic animals are being taken away from their mothers at an infant stage and brought to commercialisation. Humans have a history in acquiring wild animals and they started using them as pets together with all the other kinds of animals the last 17,000 years (Warwick et al., 2018). When the animal trade is not limited to the country of origin, and the commercialized species are exported to different countries/continents, then they are considered as alien species (Seebens et al., 2017). These alien species are invading the biodiversity of each country that imports them and their spread in the last decades until today, is taking place at a very fast pace (Seebens, 2019) as well as their use as pets. If, for example, there is a wild animal species which is captivated and kept as pet in its local region, it is not considered as non-native, consequently it is not exotic (Warwick & Steedman, 2021). It is very difficult to record the exact number of animals commercialized due to the huge amount of information or lack of data. The biggest quantity of a species is purchased as pets in an area, the greater the rate of their migration and relocation in an area (Lockwood et al., 2019). Although there is a strict legal framework regarding the ownership of wild species, social networks are crowded with thousands of reptile owners and traders in Brazil (Alves et al., 2019). Moreover, in the Philippines the reptiles pet trade is very popular, and it includes 197 exotic reptiles' taxa and at the same time, traders' interest in promoting items through social media is constantly increasing (Sy, 2015). Furthermore, the trade in exotic species raises concerns about the welfare and conservation of them, after they are sold to holders who do not have the appropriate training and education on owning such an animal, who end up being in an inappropriate environment and suffer from abuse (Warwick et al., 2018). The extensive trade in exotic species since the late 1990s has brought a new fashion to Asia and especially to Japan, of displaying exotic wildlife (mainly reptiles and birds) in Pet Cafes or Animal Cafes (Sigaud et al., 2023) (Fig. 2.7).

Fig. 2.7. Photos are derived from animal and pet Cafes in Tokyo, Japan. On the left side there is the photo from Capyneko Cafe with capybaras Tokyo Snake Cafe with snakes. On the right side it is a birds' Cafe named Kotori Cafe Ueno and the Reptiles Cafe with different kind of reptiles.

The wild pet trade of reptiles' introductions in the US had significantly decreased until 2012, although the United States are on the top of the list for the total reptile imports with 56% (Robinson et al., 2015).
The Social Media Animal Cruelty Coalition having completed a new research on social media about the commercialization of wild animals, comes to announce quantitative results concerning abusive behaviours towards animals, from beatings and sexual abuse, to mental torture (SMACC, 2022). Very often, the abuse is not carried out in a direct but in an indirect way, since the final owners of the wild animals do not have the knowledge of exactly how to handle such an animal in terms of its nutrition, the environment that they should ensure in order to grant it a quality life, its sleep, and in general its management (Lockwood et al., 2019). There is a study which accepts that the social media expresses the views of the people regarding the trade of exotic species in relation to the welfare of these animals (Warwick & Steedman, 2021).

2.4.2 Wild pet trade in Europe

Europe host the highest percentage of endangered freshwater species in the world (Collen et al., 2014). The European Union is an official party of the CITES and the European countries have adopted the legislation on the worldwide wildlife trade (De Klemm, 1993). EU has established the import permit system for all CITES species, while in addition Germany implements the same permit for species outside the list of CITES (De Klemm, 1993). Furthermore, the European Union not only follows the CITES regulation, but has established accordingly legislation for the protection of endangered species and the control of their illegal trade, requiring each member country to comply with them, as well as having established an action plan, that is constantly updated, regarding the wildlife trafficking (European Commission, 2022). According to the IUCN Red List, approximately 1/4 of all freshwater species, in Europe, are endangered (IUCN, 2022). Europe, and indeed Germany, is seen as a central trading hub for exotic animals, such as reptiles and amphibians, which are marketed due to their rarity by collectors and non-collectors alike (Altherr & Lameter, 2020). The commercialization of animals and their sale as pets is increasing worldwide, as well as the interest of European countries in this. Countries such as the Czech Republic are visited by buyers interested in ornamental aquatic animals (Kopecký et al., 2016). European Union supports and prioritises the evaluation of the animal welfare and policy (European Union, 2012, Warwick & Steedman, 2021). Positive lists is a method used in more than 10 European countries and concerns the safety, the environment and the public health prevention and protection of exotic animal species that are commercialized and available as pets (Warwick et al., 2018).

Some scientists are concerned that with the trafficking of endangered species in the European Union, in addition to the threat to biodiversity, there will be an increase in the possibility of introducing new zoonotic diseases (Halbwax, 2020). In Portugal there has been a nearly sevenfold increase in freshwater non-native species per decade compared to 50 years ago and one of the reasons is their use as pets (Anastácio et al., 2019). Given that one European species of turtle predominates, while in North America there are 6 species, then in European waters the American turtle would be highly competitive to conquer the aquatic ecosystem (Cadi & Joly, 2003). According to the European statistics, Germany is the first country in Europe with a large difference in imports of reptiles, many of which belong to freshwater biodiversity (Eurostat, 2022). It is one of the most consuming countries in terms of trade in reptiles, in legal or illegal ways (smuggling), and the search for reptile species to buy online has been very much developed (Auliya et al., 2016). Europe has the most non-native reptiles while in the same region the pond slider *Trachemys scripta* species is a case of an exotic reptile that has arisen from the US pet trade (Kopecký et al., 2019). Following the implementation of European regulations in 2008, the number of alien species into aquaculture has been reduced, thus reducing the risk of the aquarium trade (Katsanevakis et al., 2013). EU is second in reptile imports, after the US, 40% of which are iguanas (Robinson et al., 2015). Within the European countries, reptiles that belong to the IUCN Red List of Threatened species but are not yet recognized by the CITES are particularly attractive (Auliya et al., 2016).

2.4.3 Pet trade of freshwater species

The number of mammals and fish, being kept in specified areas or aquariums, recorded as alien species is declining compared to other categories of animals (Livengood et al., 2014; Seebens, 2019). Intrusion into the ecology of the ecosystem affects the native species so much, consequently the need has arisen in Brazil to ban the pet trade in alien reptiles (Alves et al., 2019). As freshwater ecosystems come under pressures from invasive species, that are encouraged and increased by the climate change factor and therefore need threat prevention and mitigation policies (Nunes et al., 2015). Several freshwater invasive species have been recorded, and even more, that have not been identified, resulting from the aquarium trade (Nunes et al., 2015). The pet trade of freshwater fauna is a significant route for alien species to be introduced in the European freshwater biodiversity zone (Nunes et al., 2015).
Freshwater fish that are caught, collected and marketed are impossible to quantify, due to the unavailability of references from the aquarium industry (Raghavan et al., 2013). Freshwater

reptiles are becoming increasingly popular among potential owners who acquire them through pet shops or even illegal trade (Sy, 2014).

Ever since some categories of animals began to enter the trade cycle and be promoted as pets or are used for ornamental purposes, the need has arisen to engage in aquariums of plenty of species, mainly fish, freshwater habitats (Rhyne et al., 2012). Research has shown that the large-bodied amphibians are more likely to be traded and the Japanese Giant *Salamander Andrias japonicus*, which is a freshwater species, has a very high trade score which indicates the probable future risk to be traded in the future (Mohanty & Measey, 2019). Furthermore, Japan has one of largest reptiles' market and they trade a lot of freshwater reptiles and especially turtles (Auliya et al., 2016).

2.4.4 Freshwater megafauna as pets

Freshwater megafauna is a target for a lot of people to own, as mentioned before, especially because of their attributes i.e. being exotic, rare or due to their size (Fig. 2.8).

Fig. 2.8. Freshwater megafauna species from the taxonomic group of mammals, fish and reptiles, kept as pets (photos derived from Instagram and Facebook). 1st row left: Julia (Instagram username: the reptilequeen13), middle: Lutra Fury (Instagram username: lutrafury), right: Alex (Instagram username: cichlinae). 2nd row left: Juliana Fortes (facebook username: world of snakes), middle: Tae Li Starlette (Instagram username: herpnerd), right: Betsy Rogers (Instagram username: snakeydoos). 3rd row left: Orel Urbina (Instagram username: urbinaorel), middle: Kenji Mak (Instagram: Kenji130), right: Tyler Hood (Instagram username: tyler_d_hood).

One advantage of large freshwater megafauna species in their final developmental stage is that they are less vulnerable to invasive species. However, these species still face challenges such as competition for food from invasive species that inhabit the same aquatic system. Another problem is hybridization, which can lead to the extinction of native species. For instance, the broadhead catfish *Clarias macrocephalus* can mate with the African catfish *Clarias gariepinus*, creating hybrids that can threaten the survival of native species (Na-Nakorn et al., 2004). European rivers and lakes are home to numerous megafauna species, including the European sturgeon *Huso huso*, which are often sought after for their striking appearance and attract global interest (Carrizo et al., 2017).

Furthermore, there is an attempt to re-introduce many megafauna species to European countries, as is the case with the Eurasian beaver (Halley, 2011). The European Atlantic sturgeon *Acipenser sturio*, which used to be spread all over the continent, is now concentrated in a specific basin France and is in danger of extinction (Williot et al., 2009).

2.5 iEcology

There are scientists who, for a few years, have been carrying out research based on digitized information to produce quantitative results about the environment and its conservation, even the relationship between nature and humans in order to enrich in new knowledge and support the scientific community (Conservation Culturomics, 2022).
The i-Ecology refers to the collection and processing of information and data concerning ecological matters, that are researched to meet other purposes and are found through the media (iEcology, 2022). This information could be produced by multiple tools in a variety of ways, a few of which are: text, pictures/photos, videos, sounds, online activity, providing new mechanisms and innovative additions to existing data (Jarić, Correia, et al., 2020). It is known that the trade abets the spread of species. With the practice of a new tool which is called i-Ecology, researchers are approaching the topics of their interest scientifically and at no particular cost, collecting information and data from digital sources, with the ultimate goal of quantifying standards in the natural world (Jarić, Correia, et al., 2020). The use of this trend these are to be explored: phenological trends, evolutionary dynamics, biotic and abiotic interactions, behaviour, changes to habitats (iEcology, 2022).
An area that could also contribute to i-Ecology is social media, where quantitative data can be explored, and recorded with the assistance of new technological means to produce interesting and useful results that will contribute to the advance of environmental sciences. i-Ecology has not yet extended to the field of freshwater megafauna, and thus there is still the potential to a dearth of research into these ecosystems and their fauna. This new method was applied to the dissertation.

2.6 Conclusions

Freshwater fauna and especially megafauna are highly threatened mainly by human factors that are affecting their quality of life, environment and living conditions. The dangers posed to freshwater ecosystems relate exclusively to different types of anthropogenic threats, either directly or indirectly. Freshwater megafauna becomes more and more interesting for the human societies to be acquired and used by them. Since freshwater ecosystems are at greater risk than other ecosystems, this potentially means that laws are more permissible, investments and conservation policies are probably insufficient. There is, unfortunately, a big gap of information and not a satisfying number of research that has been carried out, especially for a respectably large part of the world map. This fact is concerning for the evolution of these species and their future status.

An important motivation for this dissertation is the risk of alien species invasion, which occurs through their commercialization. The trade in freshwater species, either native or alien, and their use as pets potentially affects their population, raising concerns about their existence. On the other hand, the entry of invasive species in areas different from their origin, directly affects the biodiversity of ecosystems. Therefore, it is important to explore what are the impacts and the results on the freshwater megafauna species, which come from the human decision and need to commercialise them, by turning them into objects of acquisition and transaction, or disturbing capture.

Chapter 3
Methodology

3.1 Methods of data collection

This dissertation has been focused on the freshwater species that cover the size qualifications to be identified as megafauna species. Various types of data have been collected including social media posts and photos, the location where the animals are being kept as pets, the native and introduced continents of each freshwater megafauna species, the threats they face, the impact on their populations and the conservation status. Considering the Red List of the International Union for Conservation of Nature, there are 207 freshwater taxa that are contained, and this is the exact number which has been looked into for this dissertation. The IUCN is categorising the megafauna into Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild and Extinct and all these seven groups are taken into account and the data that has been collected, form the main part of the dissertation. The 207 species are of 4 taxonomic groups: fish, mammals, reptiles and amphibians. The taxa names and all the common names are comprised.

Research shows that by 2027 the social media users will 5.85 billions, the majority of which are located in East Asia occupying 26% of the global users (Statista, 2023). The active social network penetration global rate is reaching 59.4% (Statista, 2023). The data collection was carried out through the 3 biggest and of the most popular online platforms in the class of social media. Everyone can use the social networks, for the young people they have become a way of life, but also for the older people to find information, for entertainment, but also with professional or scientific reasoning (Gefter, 2006). These platforms are the following: Facebook, Instagram and Twitter. The most popular social media network as of January 2023 is Facebook, while Instagram was ranked 4th and Twitter 14th worldwide (Statista, 2023). The global internet access, the cell phones, laptops, tablets which carry the social media applications, ease the use of them (Gefter, 2006). Facebook is an online social network platform that can be used in different ways and for different purposes. It is the oldest of the 3 of the aforementioned platforms, as it was launched in February 2004 by Mark Zuckerberg (The Guardian, 2007). Although, it was initially inspired to assist the social connection between its users, it is literally encouraging the spread of thoughts, views, emotions and the daily life of people who are members of the platform to their friends or the general public and this can also be achieved in real time (P. T. Johnson et al., 2018; Kirschner, 2015). It is also researched how Facebook can be presented as an educational and learning means (Kirschner, 2015). Twitter was launched in July 2006 with 262 million users, with US users reaching 76.9 millions (Statista, 2023). It does not offer the possibility for a more private account, therefore all the tweets that are published could be seen by everyone, therefore the people that are mainly visitors of someone's posts, are to a large extent people who share the same interests (Logghe et al., 2016). Twitter has been always attracting people from the scientific and academic community due to the range of interests which a user can be benefited from, by the use of the hashtag symbol (Daneshjou et al., 2021). On the other hand, Instagram is a much newer social media site and it was found in 2010 by Kevin Systrom and Mike Krieger and it is estimated that by 2025, 1.44 billions of people will become Instagram users (Statista, 2023). Due to the probability of misinformation and unreliability of information that is being posted and published by the users of the social media, there was the need to have profound research for identifying each species and the use of it (Li & Suh, 2015). Since there is an enormous use of the social media platforms, with 4.76 billion accounts, their users are taking advantage of their popularity and more extensive exposure of what they would prefer to promote, advertise, do marketing, show or even sell. They can post photos and videos of what they choose from their personal life or business, without incurring any cost, and this fact could not be ignored by the scientific community, neither by this dissertation. Via the search box of each platform and by typing the taxa name, photos, videos, articles and in general posts about the specific taxonomic group were appearing on the screen and therefore were ready to be processed as necessary or unnecessary. If the taxa name did not present a large range of results, there was every time, and without exception, the search based on the common names. Some taxa names, such as *Hoplias aimara*, had very few results comparing to its common name Wolf fish. More specifically, on Instagram the scientific name was found to have 2,130 results while the common name had 27,225 posts as results.

The same case was the freshwater species *Acipenser gueldenstaedtii* with 236 photos whose common name (Russian sturgeon) had yielded more 930 photos. The green anaconda was found to have 15,174 results and its Latin binomial name Eunectes Murinus had only 6,000.
On Facebook and Twitter, it is not as easy to have the count of the posts or photos that are coming while typing the binomial or common name because it is not shown on the platform. Although for the *Eunectes Murinus* there are obviously more results on Facebook than on Instagram, as the scrolling down time took more than 90 scrolls down to display each page (assumingly much more than the 6,000 Instagram results) to get loaded while the common name (green anaconda) had lots of thousands of results. Some of the posts were very obviously showing that they were relevant to freshwater megafauna because of the clarity of photo, the name of the account, the tags that were used, the information that was given on the title of the post or in the comments. For example, on Twitter there was a user tracked in Minneapolis, USA, who posted a photo of a fish in a home aquarium that looked like a Russian sturgeon (*Acipenser gueldenstaedtii*) with the title 'I pet a Russian sturgeon', while on the comments they are discussing about this pet with its scientific name and on the profile of this account it is mentioned that they are hobbyist exotic fish owners. Another case on Facebook, is about owning a *Polyodon spathula* (Paddlefish). The owner has posted many photos of the fish in their home aquarium and the title is the binomial name, while in lots of other posts they mention this as their pet with also its common name and the location is clearly stated on the profile of the user. Many times, the location is on the photo too and this makes the research easier. Some other times, the location had to be asked and only the accounts that have answered all the questions were taken under consideration in this dissertation.

3.2 Identifying potential freshwater megafauna species

First, there was a process followed where the photo would be saved and categorised to the exact taxa and taxon. This presupposes the recognition of the animal, fact very important for the progress of the research. The identification of the species could be ensured by having a deeper look on their features (such as size, colour etc) but also a conversation with the owner about the information needed (Table 3.1).

Table 3.1. Confirmation of the credibility and authenticity of the photograph or video post.

Questions asked to the potential pet owner
1. Is this animal under your possession?
2. Is it a freshwater animal?
3. Do you know its scientific name?
4. Are you selling/breeding it?
5. Is it yours or someone else's pet?
6. Do you still have it?/Is it still alive?
7. Do you own more freshwater animals?
8. Do you have more photos/videos of them?

The second one was not always reliable, since lots of people that possess an animal do not have accurate knowledge about their pets. The answers played a decisive role on taking the social media account under consideration in the collection of data. Therefore, data was taken under consideration for potential collection only from people who have answered that the animals on the photos are freshwater species, they are still alive and kept and lastly it has been helpful when they could state their scientific name apart from the common name. Afterwards, the species had to be doublechecked through the IUCN and CITES lists and their main and appearance characteristics were to correspond. Except for the photos, there were also a lot of videos that have been posted including the species of interest that could not be ignored or omitted. Therefore, screenshots were taken where the animals are clearly visible, and their taxon would be acknowledged. These cases refer to larger domestic environments with more than one freshwater species coexisting, such as ponds, domestic aquariums and big glass pet houses. Consequently, one of the last questions made to the account owner were if they possess any other freshwater species and which and if they can provide visual material.

3.3 Identifying pet owners

After locating the potential freshwater megafauna species pets, the target was to reassure that they are real pet owners and not traders, breeders or just admirers of freshwater megafauna species and also find which users have them in their houses, gardens, private aquariums, ponds, which of these animals belong to them and at the same time are used as pets. It was sometimes difficult to identify contents posted by real pet owners and who are traders from who are breeding and/or selling the animals as pets. That is the reason for asking questions to ensure that the freshwater species are under their possession and not someone else's, they do not sell or breed them, and it is kept as a pet and not for other purposes. The real pet owners usually post many photos and videos of admiration towards their animals, showing their pets' skills, beauty, exotic appearance, frightening and dangerous features, as it happened in the case of the Siberian sturgeon, *Eunectes murinus* and yellow anaconda *Eunectes notaeus* for which plenty of photos have been posted every day by the same profiles. An important clue of their ownership would be a proof (usually picture) of the day they found or purchased the animal and from where (location in the wild or pet shop). They often announce new achievements of their pets or their physical development, the changes in their skin, fur, and colours, especially when it comes to reptiles. Usually, such owners are proud to show to the public their new, rare, exotic pet, consequently they choose to post a lot about them, even pose with them. Another clue would be the title of the post, while a lot of people like to write about their pets referring to them by their name or their relationship, as they often consider them family members. Furthermore, they show in general an interest in exotic animals through posts about them, or even from their profile photo which is indicating very profoundly that they are fond in these species. One more aspect is that there is someone in their circle (family, friends, colleagues) who owns a freshwater megafauna pet and influence them to adopt or buy such a pet. So, it is easier to find information about multiple possessors from someone's social media profile that is already one. Moreover, data could be collected from existing Facebook and Instagram groups that consist of people who like freshwater megafauna pets, and they have one at home or would like to have one. Similarly, in Twitter people with same interests are connected through the platform, discuss about them and share pictures. A lot of new owners of exotic pets were found through this kind of groups and discussions. There are several people who have found the animals in the wild, captivated them and kept them as pets. This refers mainly to species of megafauna fish. They have been fished accidentally from the lake or river where they live and have been transferred into a domestic private pond.

Some species were much more popular than others and many more photos were to be found and checked. For example, the Nile Crocodile, the sturgeons, catfish, anacondas, and carps were some of the animals that were more difficult to distinguish their use as pets from other uses through the social media data. Tens of thousands of results were under research for some of the mentioned species and not just in one platform. Although there were plenty of articles on the social media and hundreds or thousands of results, some animals did not conclude to have been detected as pets, such examples are the lake sturgeon, gulf sturgeon and Russian sturgeon. That is due to extensive exploitation of them (fishing), and a big percentage of the photos is showing the prey of anglers and professional fishermen. On the contrary, other species had lots of results and at the same time an interesting and rich outcome for the dissertation, i.e., the paroon shark, *caiman crocodilus*, *Paleosuchus palpebrosus* and the *Macrochelys temminckii*. There were some articles on newspapers, websites, news and online articles about species that people use as pets, however there was almost nothing found in the social media platforms which made it complicated to come to conclusions. An example is the capybara (*Hydrochoerus hydrochaeris*) for which were no results found on Facebook, Instagram and Twitter and the Nile Crocodile where it was known that citizens of countries in the north of Africa captivate them, bring them home and raise them until they reach a point in their life where they are again released to the wild, nevertheless the few data collected were not from this location.

The total number of records that were derived is 681, including pictures, videos and posts. The most effective sources in this research were Instagram, then Facebook and last was the Twitter. In total 540 screenshots were included in those collected, from which Instagram had 470 screenshots taken, Facebook 56 and Twitter only 14. Derived data from Instagram assisted this dissertation and a very big number of photos were open to the public from users. The positive upshot of Instagram owing to the nature of the platform where the accounts usually post photos/reels/videos/stories, is also the easy access to them and the clear definitions of what it is shown by using the '#' and scientific terms. Accordingly, it is more convenient for the readers to reach to the information they request. In addition, it could be mentioned that the approximation of the pet owner is efficient and there was a big chance that a short conversation was conducted, and a lot of important questions were answered.

On the other hand, Facebook is a platform that is used longer and by a greater age range, hence a big part of the advantageous data in this paper are from the past years and not very recent. That is the reason why it had to be questioned if the animals have passed away and their use as pets is no longer valid. Nonetheless, some owners buy/adopt/own more than one species and there is no limitation in their future posts after the death of one of their pets. There were, as well, more groups found on Facebook, than on the other two platforms of people that have domesticated an exotic animal but needed to be accessed by approved members. This assumed the creation of a convincing social media profile in order to be accepted by such groups (name, profile pictures, posts and reposts).

Additionally, Twitter includes also the easy access through the '#' like Instagram. It could be characterised as a platform that is highly used from the scientific community to share their interests, findings, plenty of different scientific publications and have zestful conversations with colleagues from all over the world, achieving professional networking and getting profited by the advertisement of their own work. Instead, Twitter has not enriched this dissertation's data sheets, and it did not contribute to the research outcome. It seems that freshwater megafauna pet owners are not interested in flaunting their pets to the public through this platform. Therefore, the biggest part of the database that has been formed for the dissertation was based mainly on Facebook and Instagram.

3.4 Establishment of the database

The social media research process was initiated in November 2020 with the creation of the primary database, which was updated every two weeks until May 2021. During this period, all confirmed information was edited and classified. In December 2021, recurrent research was conducted to collect additional data from social media platforms, and this continued until April 2022. All updated elements were double-checked in August 2022 until the end of September 2022 to ensure the validity and reliability of the potentially modified information. The post-litigation stage involved further research on the existing database, specifically the global and European situation of freshwater megafauna species and individuals (Fig. 3.1).

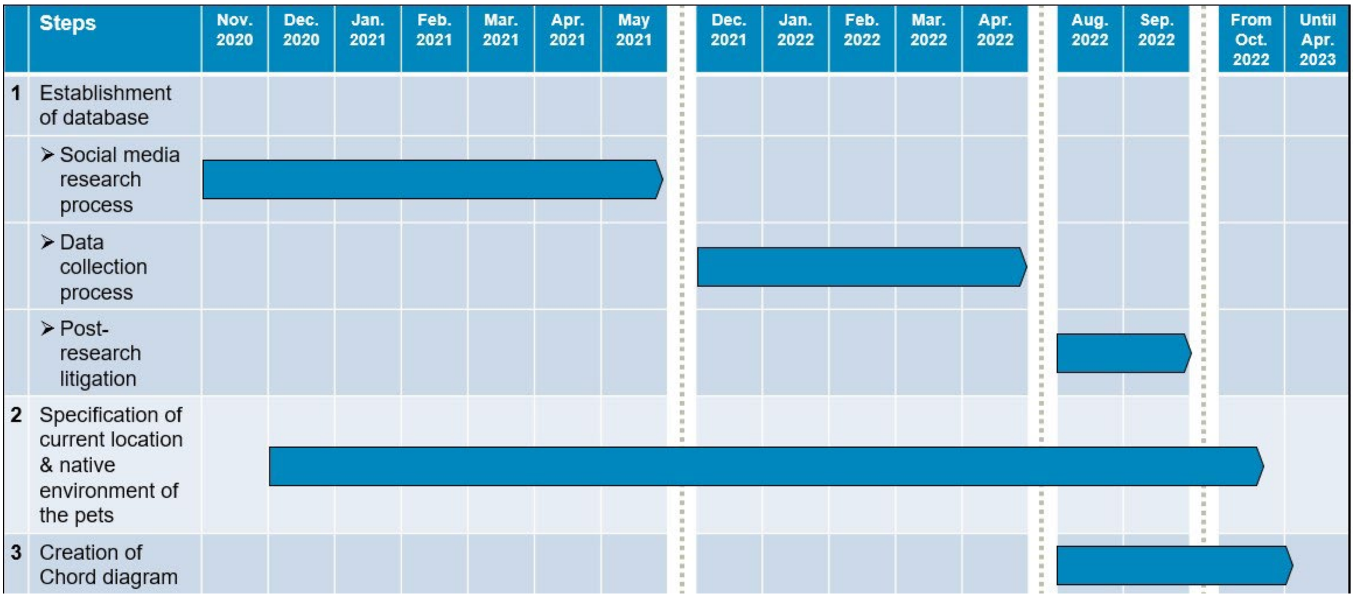

Fig. 3.1. This figure shows the completion steps of the dissertation.

The data collection process began with the formation of a Red List based on the IUCN database, which included all 207 freshwater megafauna species, their taxa names, taxonomical groups, classes, orders, families, common names, and Red List categories (He et al., 2018). This formed the foundation of the research, which sought to identify the extent of the wildlife trade in freshwater megafauna species through social media platforms. The database was continually updated and refined to ensure its accuracy and relevance to the research objectives. By conducting a comprehensive analysis of the social media data, the research aimed to raise awareness of the negative impacts of the wildlife trade on freshwater megafauna species and to promote ethical and responsible pet ownership practices.

There was also another process of distinguishing which freshwater megafauna species that are part of the Red List of IUCN, are at the same time listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora and this information is derived from the database of Species + (CITES, 2022, SpeciesPlus, 2022). Furthermore, other important information was derived as well from the IUCN database, such as the native geographical range, the population trend, the threats for each species and, of course, the category of the Red List assessment. The native range that could not be satisfied by the IUCN database, was derived from the NatureServe database (IUCN, 2022, Nature Serve,2022).

During the research process, several main categories were identified as relevant and were consistently recorded, including the taxa name, taxon, and common name. Additionally, each photo was numbered and categorized according to the corresponding species. To keep a record of all visual evidence gathered from social media platforms, a separate folder was created, which included pictures, video screenshots, and other relevant screenshots, such as messages and comments that specifically identified the species and confirmed their use as pets. In total, 539 photos and screenshots were collected and incorporated into the dissertation. To facilitate the classification and accessibility of the data, additional columns were added to the database, which included identification numbers for each species and corresponding picture. By adding these columns, the data could be easily sorted and accessed for analysis. Apart from the visual elements, the comments that verify the confirmation of the pet ownership will be added up in the lists. Another thing that would improve the easier application of the data was to save the exact website address links according to every founding from the social media profiles. The validity of the data depends on the date of the posts. If the post was presented a few or more years back, there is the probability that the situation has been altered. The pet owner might no longer possess the animal, has given it away, released it to the wild, sold it or the pet has died. In that case, the data was excluded from the database. A significant aspect that should be recorded was the location where the species were found to be resided, meaning the country and city. This would satisfy the part where the comparison of the native region of the species and the region where it is kept is taking place. This would be announced (tagged) from the social media user and if not, it would be extracted through a crosstalk. The question if the animal which was found online and is shown in the visual evidence, is for sure possessed as a pet or not, determines its participation in the database, hence it was the last step included. This stage identified the elements that remained and took part in the further research procedure. The initial phase of the establishment of the database was assuming the satisfying responses on all the questions mentioned above. This could last longer for the finalisation, due to the pending inquiries. Lastly, the rows were coloured to distinguish which would be employed and which not. Green colour for the useful information, red for the not useful and orange for the pending ones. Some rows remained orange coloured until the end of the research and therefore did not take place. The data that was coloured orange, is the data which was edited and looked into until the completion of the social media research.

The second stage of the database creation included the specification of the continent and the country where the pet was found to be living. An element which is a goal for this dissertation to be elaborated, is to what extend are these freshwater megafauna species alien to the environment they are kept and what are the impacts of this phenomenon. Therefore, it is important to locate the exact areas where the species live and where is their native environment. It is not a rare occasion that a part of the pets' population is considered to be exotic to the country they exist. At a further phase of this stage and according to the species identification, there is the creation of a table with columns that are consisted by the number of the species and the records of the native and alien freshwater megafauna. The native area is usually more than one country or even continent. Subsequently, there is the step of categorisation of the sampling as such: species ID, location (as specific as possible), native countries.

The third and last stage is consisted by the creation of a diagram showing the comparisons and links between the exporting continents (native continent of the freshwater megafauna species) and the importing continents (where the freshwater megafauna species are kept as pets). These links were created using the R language and they are shown through the Chord diagram. It is a prerequisite to make a table with the identification of the species, the native continent and the introduced continent. Each species which is used as pet in a region/continent, through diagrams, tables and graphs, is linked to its native environment. Most of the freshwater megafauna are found to be native in Asia with the region of North America in the second place (Fig. 3.2).

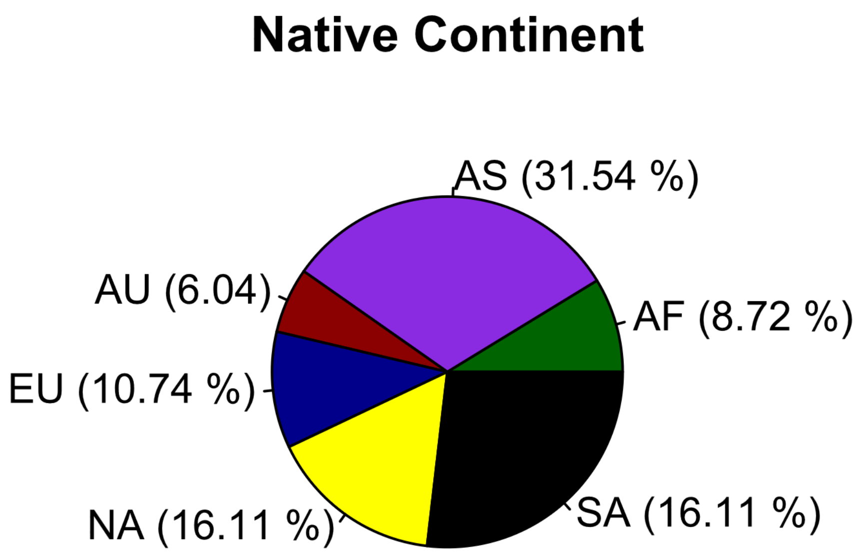

Fig 3.2. This graph shows where the 207 freshwater megafauna species' native continents (IUCN,2022). AS stands for Asia, AF for Africa, AU for Australia, EU for Europe, SA for South America and NA for North America.

Therefore, the last part of this dissertation focuses in the areas where the pets are located and how expected or unforeseen this is, as well as the consequences of this status and to what extent this situation affects the environment.

Chapter 4

Results

In this chapter, the results of the three stages which were developed in the previous chapter are presented and it is defined what is the main strategic framework of the research. This framework is about:

1. finding freshwater large-bodied species that are used as pets, identifying them as pets on social networking media, and identifying pet owners.
2. the development of a database with the aim of studying the level that the species' populations are native or alien in relation to the region where they were found to live, as well as the extent that the species were found to occupy on a global level and lastly,
3. the links and comparison between the introduced regions and the exported ones.

The parameters that were studied, initially, refer to the possession of the species for private use, as the research related to their status of being native or not is also considered very important. Furthermore, the records which were collected from the social media platforms (Instagram, Facebook, Twitter) and the extraction of effective data from each of them, as well as the species of freshwater megafauna and the frequency on which they appear on these websites/online apps. Another thing that emerged from this analysis is the extent to which the data refer to threatened species, also in relation to their taxonomic group. Despite that and in addition to the analysis of the IUCN Red List, an analysis of the CITES lists is also carried out. According to the CITES and by sourcing information from the Species+ database, 102 species are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2022, Species Plus, 2022).

Another key point that emerged through the analysis, is the identification of the impacts of the alien species on the environment and ecosystems, while also the impact on a social and economic level. The Environmental Impact Classification for Alien Taxa (EICAT) is a tool created to prioritise non-native species that affect negatively the environment, and the framework and global database is published on IUCN (IUCN, 2022). On the contrary, the EICAT+ framework is created to assist the classification of the positive impacts of alien species on the native biodiversity (Vimercati et al., 2022). Provided that, the invasions lead to socio-economic impacts that are quantified through the SEICAT which classifies the species and assigns the impacts in levels (Bacher et al., 2018).

In order to create the maps that will show the results from the records that have been gathered, it is needed to sum up the total of the species per country, together with the native and alien records, as well, by country. Thereafter, the creation of the three maps takes place. The first map is showing the number of freshwater megafauna used as pets in relation to the total number of pets per country. The second is presenting the number of native species in relation to the total number of freshwater megafauna pets per country and the last one, similarly, is referring to the alien species in relation to the global pet records.

Another interesting outcome is to observe the level on which every social media platform has enriched the database of this dissertation.

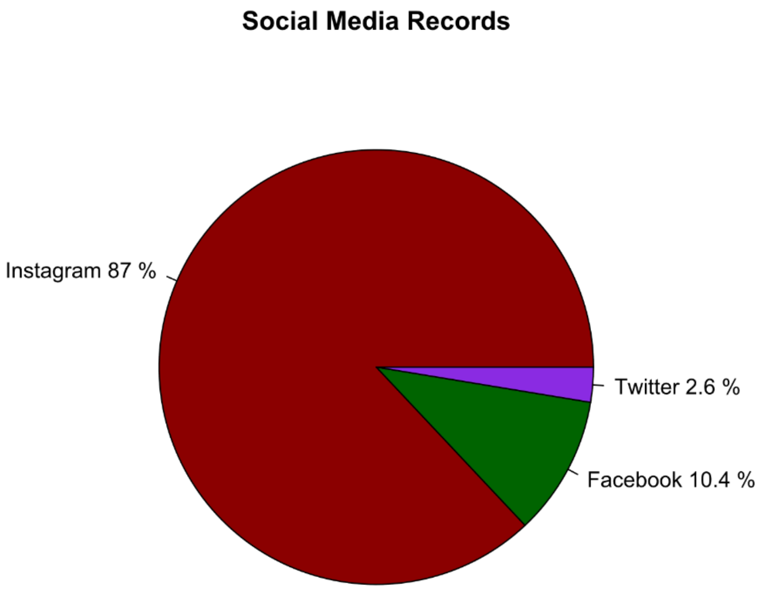

Fig. 4.1. Social media records that were collected per platform for every freshwater megafauna that was found to be used as pet.

From the total number of 207 freshwater megafauna species, 140 species had no records on social media that could identify them as pets. The number of records which were used in this dissertation are 372 and the number of species 67, although the total number of records that had been initially collected was 681 but not all of them could be used for this dissertation (Table 4.1).

Table 4.1. The complete list of the freshwater megafauna species that were found to be used as pets though the social media research.

Binomial Name	Common Name	Taxonomic Group
Acipenser baerii	Siberian sturgeon	Fish
Acipenser dabryanus	Yangtze Sturgeon, River Sturgeon, Dabry's Sturgeon	Fish
Acipenser fulvescens	Lake Sturgeon	Fish
Acipenser gueldenstaedtii	Russian sturgeon	Fish
Acipenser schrenckii	Amur Sturgeon	Fish
Acipenser sinensis	Chinese Sturgeon	Fish
Acipenser stellatus	Stellate Sturgeon, Sevruga, Star Sturgeon	Fish
Acipenser sturio	Common Sturgeon, Atlantic Sturgeon, Baltic Sturgeon, German Sturgeon	Fish
Atractosteus spatula	Alligator gar	Fish
Arapaima gigas	Arapaima, Pirarucu	Fish
Arapaima leptosoma		Fish
Brachyplatystoma filamentosum	Kumakuma	Fish
Brachyplatystoma rousseauxii	Gilded catfish	Fish
Catlocarpio siamensis	Giant Carp, Giant Barb	Fish
Clarias gariepinus	African Catfish, Sharptooth Catfish, Catfish, Common Catfish, Mudfish, Barbel, Sharptoothed Catfish	Fish
Colossoma macropomum	Cachama	Fish
Ctenopharyngodon idella	Grass Carp	Fish
Hemibagrus wyckioides	Asian Red Tailed Catfish, Red fin bagrus	Fish
Huso dauricus	Kaluga	Fish
Huso huso	Beluga, Giant Sturgeon, European Sturgeon, Great Sturgeon	Fish
Hydrocynus goliath	Giant tigerfish	Fish
Lates calcarifer	Barramundi	Fish
Lates niloticus	Nile Perch, Victoria Perch, African Snook	Fish
Maccullochella peelii	Murray Cod, Murray River Cod	Fish
Pangasius sanitwongsei	Giant Pangasius, Paroon Shark, Pangasid-catfish, Pla Thepa	Fish
Pseudoplatystoma fasciatum	Barred sorubim	Fish
Polyodon spathula	Paddlefish, Spadefish, Duckbill Cat, Spoonbill Cat	Fish
Probarbus jullieni	Jullien's Golden Carp, Seven-striped Barb	Fish
Probarbus labeamajor	Thicklipped Barb	Fish
Scaphirhynchus albus	Pallid Sturgeon	Fish
Tor putitora	Putitor Mahseer, Golden Mahaseer	Fish
Wallago attu	Wallago; Lanchi	Fish

Silurus asotus	Amur catfish, Chinese catfish , Japanese catfish	Fish
Myxocyprinus asiaticus	Chinese sucker	Fish
Lepisosteus osseus	Longnose Gar	Fish
Potamotrygon motoro	Ocellate River Stingray	Fish
Neoceratodus forsteri	Australian lungfish	Fish
Bagarius yarrelli	Giant Devil Catfish, Giant Painted Catfish, Sand Shark (www.planetcatfish.com)	Fish
Channa marulius	Great snakehead	Fish
Phractocephalus hemioliopterus	Redtail catfish	Fish
Pangasius pangasius	Pangas catfish	Fish
Lates japonicus	Japanese lates	Fish
Pangasianodon hypophthalmus	Striped Catfish	Fish
Clarias macrocephalus	Broadhead Catfish	Fish
Hoplias aimara	Anjumara, Wolf Fish	Fish
Salminus brasiliensis	Dorado	Fish
Protopterus aethiopicus	Marbled lungfish	Fish
Electrophorus electricus	Electric eel	Fish
Zungaro jahu	Manguruyu	Fish
Ictalurus furcatus	Blue Catfish	Fish
Ictiobus bubalus	Smallmouth buffalo	Fish
Ictiobus cyprinellus	Bigmouth Buffalo	Fish
Labeo rohita	Rohu	Fish
Lates angustifrons	Tanganyika Lates	Fish
Lates calcarifer	Barramundi	Fish
Lates japonicus	Japanese lates	Fish
Lates niloticus	Nile Perch, Victoria Perch, African Snook	Fish
Lepisosteus osseus	Longnose Gar	Fish
Lota lota	Burbot	Fish
Luciobarbus esocinus	Pike Barbel	Fish
Luciocyprinus striolatus	Striped Pikecarp	Fish
Maccullochella ikei	Eastern freshwater cod	Fish
Maccullochella mariensis	Mary River Cod	Fish
Maccullochella peelii	Murray Cod, Murray River Cod	Fish
Megalops atlanticus	Tarpon	Fish
Morone saxatilis	Striped Bass	Fish
Mylopharyngodon piceus	Black carp	Fish
Myxocyprinus asiaticus	Chinese sucker	Fish
Neoceratodus forsteri	Australian lungfish	Fish
Oncorhynchus tshawytscha	Chinook Salmon	Fish
Pangasianodon gigas	Mekong Giant Catfish, Giant Catfish	Fish
Pangasianodon hypophthalmus	Striped catfish	Fish
Pangasius pangasius	Pangas catfish	Fish
Pangasius sanitwongsei	Giant Pangasius, Paroon Shark, Pangasid-catfish, Pla Thepa	Fish

Parahucho perryi	Sakhalin Taimen, Ito, Japanese Huchen, Sea-run Taimen	Fish
Paratrygon ajereba	Manzana Ray, Ceja Ray	Fish
Phractocephalus hemioliopterus	Redtail catfish	Fish
Polydactylus macrochir	Grand Threadfin	Fish
Polyodon spathula	Paddlefish, Spadefish, Duckbill Cat, Spoonbill Cat	Fish
Potamotrygon brachyura	Short-tailed river stingray	Fish
Potamotrygon motoro	Ocellate River Stingray	Fish
Pristis pristis	Largetooth Sawfish	Fish
Probarbus jullieni	Jullien's Golden Carp, Seven-striped Barb	Fish
Probarbus labeamajor	Thicklipped Barb	Fish
Protopterus aethiopicus	Marbled lungfish	Fish
Psephurus gladius	Chinese Paddlefish, Chinese Swordfish, White Sturgeon	Fish
Pseudoplatystoma corruscans	Spotted sorubim	Fish
Pseudoplatystoma fasciatum	Barred sorubim	Fish
Ptychocheilus lucius	Colorado Pikeminnow, Colorado Squawfish, Colorado Squafish, Colorado River Squawfish	Fish
Pylodictis olivaris	Flathead Catfish	Fish
Rita sacerdotum	Salween rita	Fish
Salminus brasiliensis	Dorado	Fish
Salmo marmoratus	Marble trout	Fish
Salmo salar	Atlantic Salmon, Black Salmon	Fish
Salmo trutta	Brown Trout, Sea Trout	Fish
Salvelinus namaycush	Lake trout	Fish
Scaphirhynchus albus	Pallid Sturgeon	Fish
Sciades couma	Couma sea catfish	Fish
Scomberomorus sinensis	Chinese Seerfish	Fish
Silurus asotus	Amur catfish	Fish
Silurus glanis	Wels Catfish	Fish
Silurus soldatovi	Soldatov's catfish	Fish
Silurus meridionalis	Chinese large-mouth catfish	Fish
Sorubimichthys planiceps	Firewood catfish	Fish
Stenodus nelma		Fish
Tor putitora	Putitor Mahseer, Golden Mahaseer	Fish
Tor tor	Tor barb	Fish
Urogymnus polylepis	Giant freshwater stingray	Fish
Urogymnus ukpam	Pincushion Ray,Thorny Freshwater Stingray	Fish
Wallago attu	Wallago	Fish
Wallago leerii	Helicopter Catfish?	Fish
Wallago micropogon		Fish
Zungaro jahu	Manguruyu	Fish
Zungaro zungaro	Guilded Catfish	Fish

Aonyx capensis	African Clawless Otter, Cape Clawless Otter	Mammal
Aonyx congicus	Congo Clawless Otter, Zaire Clawless Otter, Small-clawed Otter, Small-toothed Clawless Otter, Cameroon Clawless Otter	Mammal
Blastocerus dichotomus	Marsh Deer	Mammal
Bubalus arnee	Wild Water Buffalo	Mammal
Castor canadensis	American Beaver	Mammal
Castor fiber	Eurasian Beaver	Mammal
Choeropsis liberiensis	Pygmy Hippopotamus	Mammal
Hippopotamus amphibius	Hippopotamus, Hippo	Mammal
Hydrochoerus hydrochaeris	Capybara	Mammal
Inia araguaiaensis	Araguaian boto	Mammal
Inia boliviensis	Bolivian river dolphin	Mammal
Inia geoffrensis	Amazon River Dolphin	Mammal
Kobus leche	Southern Lechwe	Mammal
Kobus megaceros	Nile Lechwe	Mammal
Lipotes vexillifer	Baji, Yangtze River Dolphin	Mammal
Neophocaena asiaeorientalis ssp. asiaeorientalis	Yangtze Finless Porpoise	Mammal
Orcaella brevirostris	Irrawaddy Dolphin, Snubfin Dolphin	Mammal
Phoca vitulina ssp. mellonae	Ungava Seal	Mammal
Platanista gangetica ssp. gangetica	Ganges River Dolphin	Mammal
Platanista gangetica ssp. minor	Indus River Dolphin	Mammal
Pteronura brasiliensis	Giant Otter, Giant Brazilian Otter	Mammal
Pteronura brasiliensis	Giant otter, Giant Brazilian otter	Mammal
Pusa caspica	Caspian Seal	Mammal
Pusa hispida ssp. ladogensis	Ladoga Seal	Mammal
Pusa hispida ssp. saimensis	Saimaa ringed seal	Mammal
Pusa sibirica	Baikal Seal	Mammal
Sotalia fluviatilis	Tucuxi	Mammal
Tapirus bairdii	Baird's Tapir, Central American Tapir	Mammal
Tragelaphus spekii	Sitatunga, Marshbuck	Mammal
Trichechus inunguis	Amazonian Manatee, South American Manatee	Mammal
Trichechus manatus	American Manatee, West Indian Manatee	Mammal
Trichechus senegalensis	African Manatee, West African Manatee	Mammal
Alligator mississippiensis	American Alligator, Mississippi Alligator	Reptile
Alligator mississippiensis	American Alligator, Mississippi Alligator	Reptile
Alligator sinensis	Chinese Alligator, China Alligator	Reptile
Alligator sinensis	Chinese Alligator	Reptile

Amyda cartilaginea	Asiatic Softshell Turtle, Southeast Asian Softshell Turtle	Reptile
Amyda cartilaginea	Asiatic Softshell Turtle, Southeast Asian Softshell Turtle	Reptile
Apalone ferox	Florida Softshell Turtle	Reptile
Apalone ferox	Florida Softshell Turtle	Reptile
Caiman crocodilus	Common Caiman, Spectacled Caiman	Reptile
Caiman crocodilus	Common Caiman, Spectacled Caiman	Reptile
Caiman latirostris	Broad-snouted Caiman	Reptile
Caiman latirostris	Broad-snouted Caiman	Reptile
Caiman yacare	Yacaré	Reptile
Chitra chitra	Southeast Asian Narrow-headed Softshell Turtle	Reptile
Chitra indica	Indian Narrow-headed Softshell Turtle	Reptile
Chitra vandijki	Burmese Narrow-Headed Softshell Turtle	Reptile
Crocodylus acutus	American Crocodile	Reptile
Crocodylus intermedius	Orinoco Crocodile	Reptile
Crocodylus johnsoni	Australian Freshwater Crocodile	Reptile
Crocodylus mindorensis	Philippines Crocodile	Reptile
Crocodylus moreletii	Morelet's Crocodile, Belize Crocodile	Reptile
Crocodylus niloticus	Nile Crocodile	Reptile
Crocodylus niloticus	Nile Crocodile	Reptile
Crocodylus novaeguineae	New Guinea Crocodile	Reptile
Crocodylus palustris	Mugger	Reptile
Crocodylus porosus	salt-Water Crocodile, Estuarine Crocodile	Reptile
Crocodylus porosus	Salt water Crocodile	Reptile
Crocodylus rhombifer	Cuban Crocodile	Reptile
Crocodylus siamensis	Siamese Crocodile	Reptile
Crocodylus siamensis	Siamese Crocodile	Reptile
Eunectes beniensis	Bolivian anaconda, Beni anaconda	Reptile
Eunectes deschauenseei	Dark Spotted Anaconda	Reptile
Eunectes murinus	Anaconda	Reptile
Eunectes murinus	Anaconda	Reptile
Eunectes notaeus	Yellow Anaconda	Reptile
Eunectes notaeus	Yellow Anaconda	Reptile
Gavialis gangeticus	Gharial	Reptile
Macrochelys temminckii	Alligator Snapping Turtle	Reptile
Macrochelys temminckii	Alligator Snapping Turtle	Reptile
Mecistops cataphractus	African Slender-snouted Crocodile	Reptile
Melanosuchus niger	Black Caiman	Reptile
Nilssonia gangetica	Indian Softshell Turtle	Reptile
Nilssonia gangetica	Indian Softshell Turtle	Reptile
Nilssonia leithii	Leith's Softshell Turtle	Reptile
Nilssonia nigricans	Black Soft-shell Turtle, Black Softshell Turtle	Reptile

Orlitia borneensis	Bornean River Turtle, Malaysian Giant Turtle	Reptile
Orlitia borneensis	Bornean River Turtle, Malaysian Giant Turtle	Reptile
Osteolaemus osborni	Congo Dwarf crocodile	Reptile
Osteolaemus tetraspis	African Dwarf Crocodile, West African Dwarf Crocodile	Reptile
Osteolaemus tetraspis	African Dwarf Crocodile, West African Dwarf Crocodile	Reptile
Paleosuchus palpebrosus	Dwarf Caiman, Cuvier's Smooth-fronted Caiman	Reptile
Paleosuchus palpebrosus	Dwarf Caiman	Reptile
Paleosuchus trigonatus	Smooth-fronted Caiman, Schneider's Smooth-fronted Caiman	Reptile
Paleosuchus trigonatus	Smooth-fronted Caiman	Reptile
Pelochelys bibroni	Asian Giant Softshell Turtle, Southern New Guinea giant softshell turtle	Reptile
Pelochelys cantorii	Cantor's Giant Softshell, Frog-faced Softshell Turtle	Reptile
Pelochelys signifera	Northern New Guinea Giant Softshell Turtle	Reptile
Podocnemis expansa	South American River Turtle, Arrau turtle	Reptile
Rafetus swinhoei	Yangtze Giant Softshell Turtle	Reptile
Tomistoma schlegelii	False Gharial	Reptile
Trionyx triunguis	African Softshell Turtle	Reptile

These results were divided into categories concerning the records (Fig. 4.2) and species (Fig 4.3).

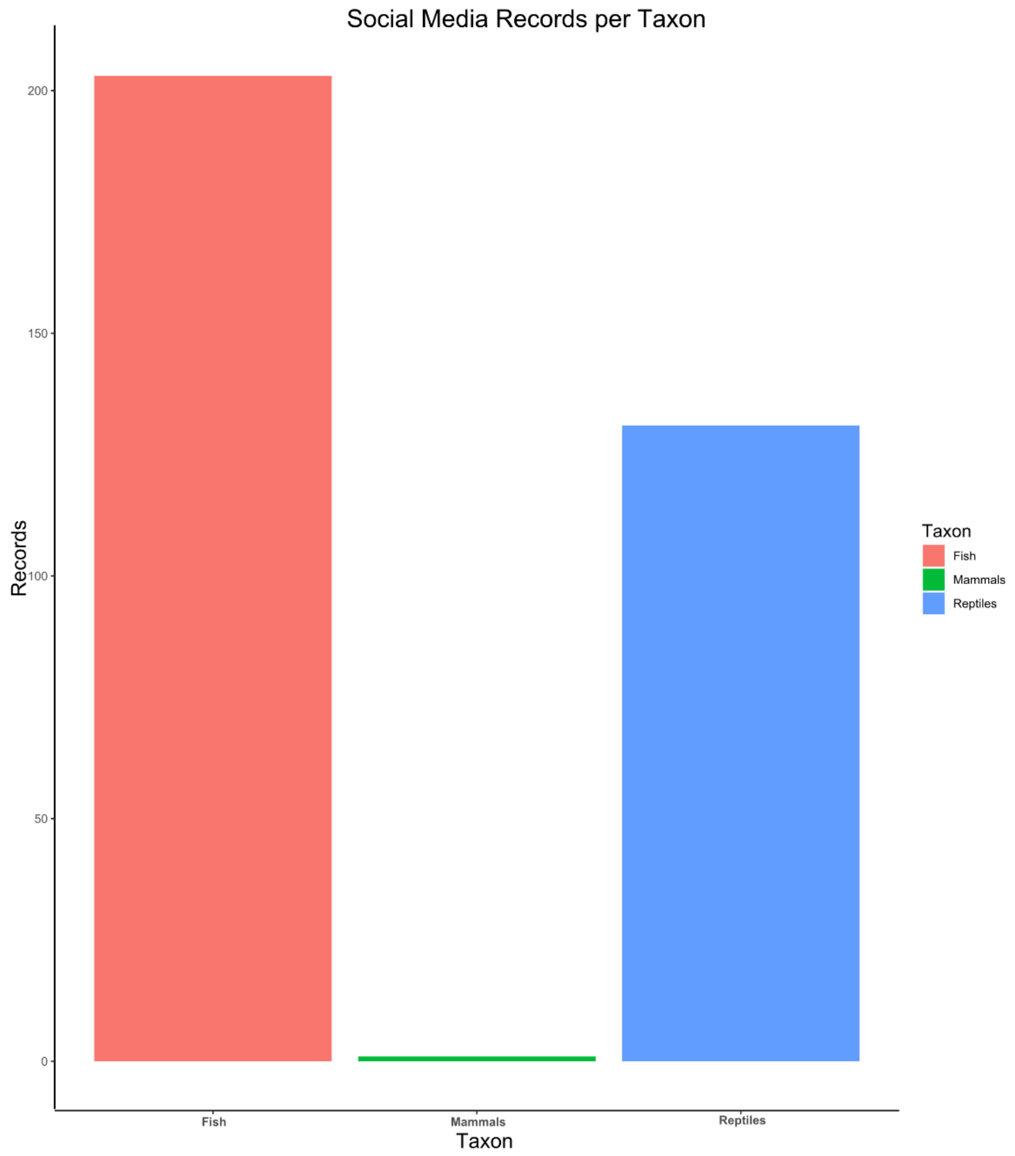

Fig. 4.2. Records of freshwater megafauna pets that were derived from the 3 social media platforms (Instagram, Twitter, Facebook) according to which taxonomic group they belong.

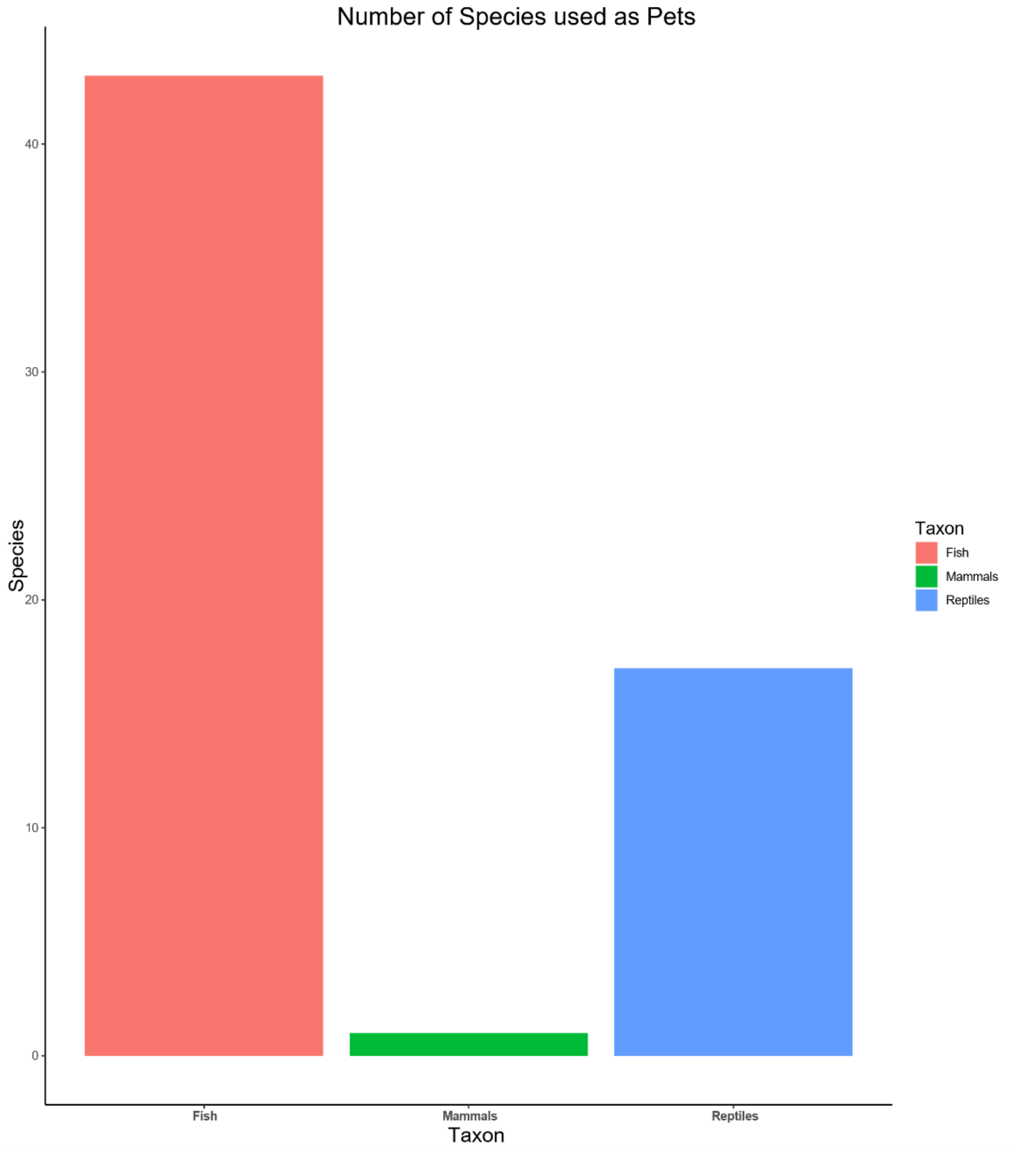

Fig. 4.3. The species that were found in social media to be used as pets according to their taxonomic group.

Table 4.2. This table shows which countries have given the most social media records of freshwater megafauna pets.

Country	Records
United States of America	67
Indonesia	44
Japan	23
United Kingdom	17
Canada	10
Germany	10

Table 4.3. The 10 freshwater megafauna species with most records on the social media that prove they are used as pets.

Binomial Name	Taxon	Total records	Asia	Europe	Africa	South America	North America	Australia
Acipenser baerii	Fish	18	4	9	0	0	5	0
Clarias gariepinus	Fish	15	4	2	1	0	8	0
Lepisosteus osseus	Fish	15	8	0	0	1	7	0
Neoceratodus forsteri	Fish	12	8	2	0	0	1	1
Pangasius sanitwongsei	Fish	24	14	2	0	1	7	0
Apalone ferox	Reptile	12	1	2	0	1	8	0
Caiman crocodilus	Reptile	13	3	3	1	0	6	0
Eunectes murinus	Reptile	22	10	10	0	2	0	0
Eunectes notaeus	Reptile	17	2	7	0	0	8	0
Macrochelys temminckii	Reptile	16	5	6	0	0	5	0

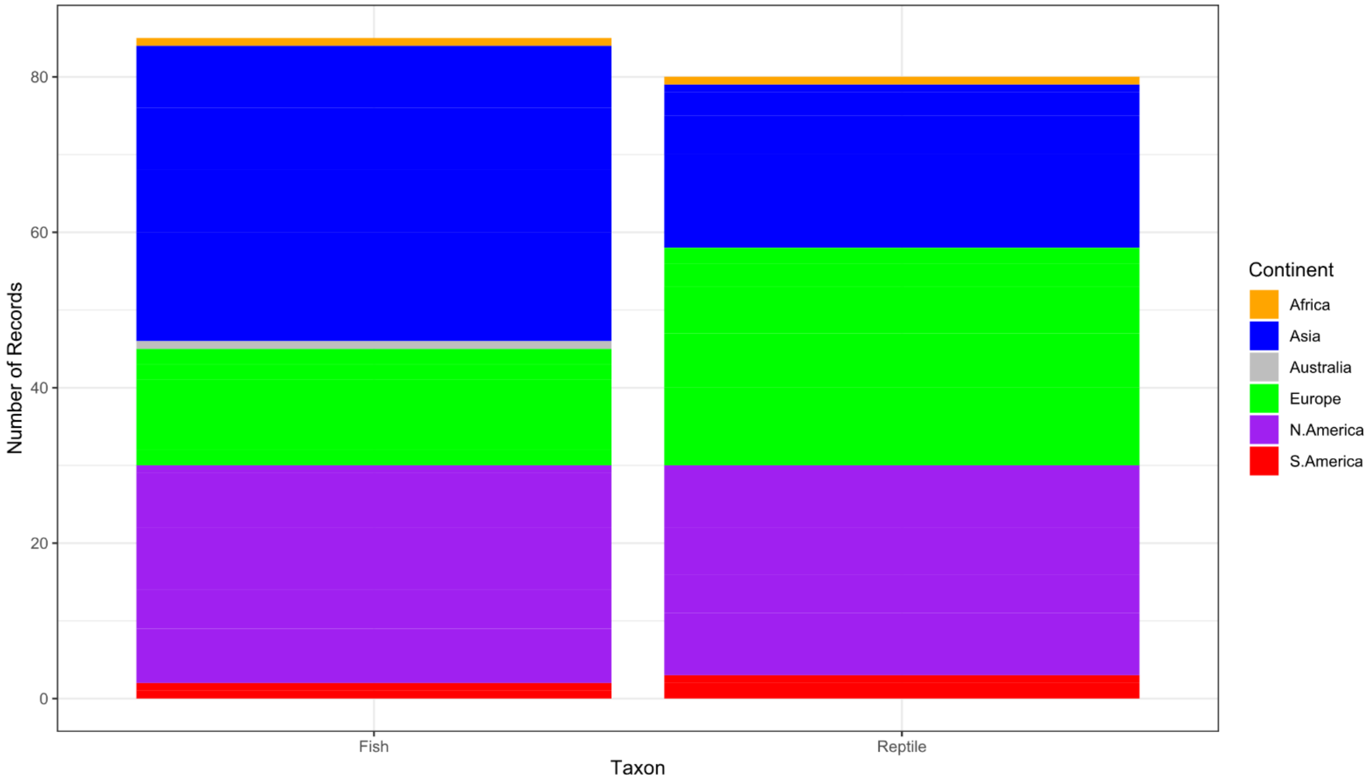

Fig. 4.4. Number of freshwater megafauna pet records on social media per continent, for the species on the top 10 for records as shown on the previous table (Table 4.2).

Table 4.4. Freshwater megafauna species that are used as pets according to the social media posts.

Binomial Name	Taxon	Binomial Name2	Taxon3
Acipenser baerii	Fish	Huso huso	Fish
Acipenser fulvescens	Fish	Hydrocynus goliath	Fish
Acipenser gueldenstaedtii	Fish	Lates calcarifer	Fish
Acipenser schrenckii	Fish	Lates japonicus	Fish
Acipenser sinensis	Fish	Lates niloticus	Fish
Acipenser stellatus	Fish	Lepisosteus osseus	Fish
Acipenser sturio	Fish	Maccullochella peelii	Fish
Arapaima gigas	Fish	Myxocyprinus asiaticus	Fish
Arapaima leptosoma	Fish	Neoceratodus forsteri	Fish
Atractosteus spatula	Fish	Pangasianodon hypophthalmus	Fish
Bagarius yarrelli	Fish	Pangasius pangasius	Fish
Brachyplatystoma filamentosum	Fish	Pangasius sanitwongsei	Fish
Brachyplatystoma rousseauxii	Fish	Phractocephalus hemioliopterus	Fish
Catlocarpio siamensis	Fish	Polyodon spathula	Fish
Channa marulius	Fish	Potamotrygon motoro	Fish
Clarias gariepinus	Fish	Probarbus jullieni	Fish
Clarias macrocephalus	Fish	Probarbus labeamajor	Fish
Colossoma macropomum	Fish	Protopterus aethiopicus	Fish
Ctenopharyngodon idella	Fish	Psephurus gladius	Fish
Electrophorus electricus	Fish	Pseudoplatystoma fasciatum	Fish
Hemibagrus wyckioides	Fish	Salminus brasiliensis	Fish
Hoplias aimara	Fish	Scaphirhynchus albus	Fish
Huso dauricus	Fish	Silurus asotus	Fish
Alligator mississippiensis	Reptile	Tor putitora	Fish
Alligator sinensis	Reptile	Wallago attu	Fish
Amyda cartilaginea	Reptile	Zungaro jahu	Fish
Apalone ferox	Reptile	Pteronura brasiliensis	Mammal
Caiman crocodilus	Reptile	Macrochelys temminckii	Reptile
Caiman latirostris	Reptile	Nilssonia gangetica	Reptile
Crocodylus niloticus	Reptile	Orlitia borneensis	Reptile
Crocodylus porosus	Reptile	Osteolaemus tetraspis	Reptile
Crocodylus siamensis	Reptile	Paleosuchus palpebrosus	Reptile
Eunectes murinus	Reptile	Paleosuchus trigonatus	Reptile
Eunectes notaeus	Reptile		

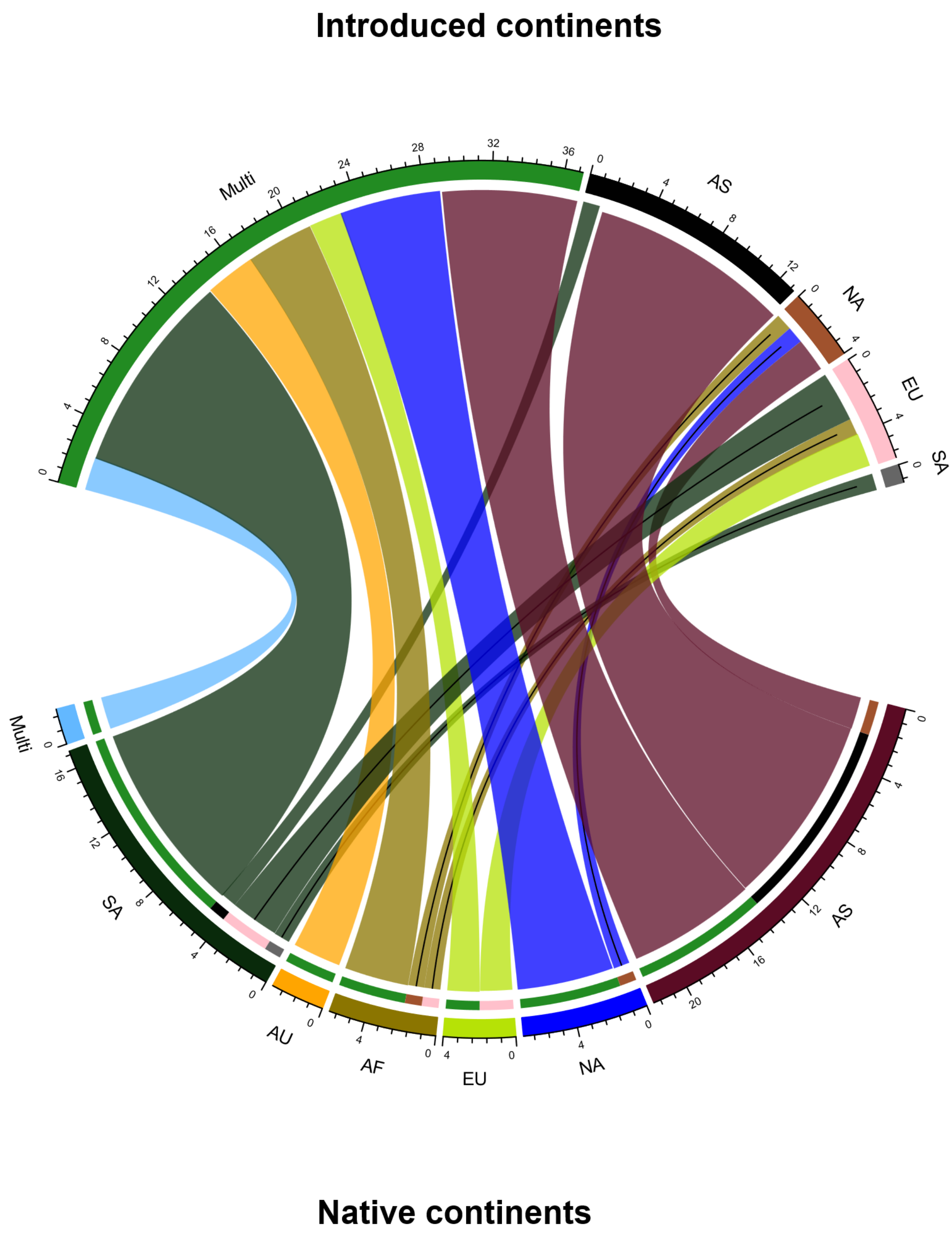

Fig. 4.5. Links between the native and introduced continents for the species that were found to be owned as pets. SA stands for South America, AU stands for Australia, AF stands for Africa, EU stands for Europe, NA stands for North America, AS stands for Asia and Multi stands for a multiple number of continents.

In the Fig. 4.5 it is shown which freshwater megafauna species were found to be introduced as pets to a continent other than their local region. The colours show the flow of the species starting from the native continent (bottom part of the Chord diagram) and ending to the introduced continent (upper part of the Chord diagram). The width of the colour in every link indicates the number of the freshwater megafauna species as indicated by the numbers written.

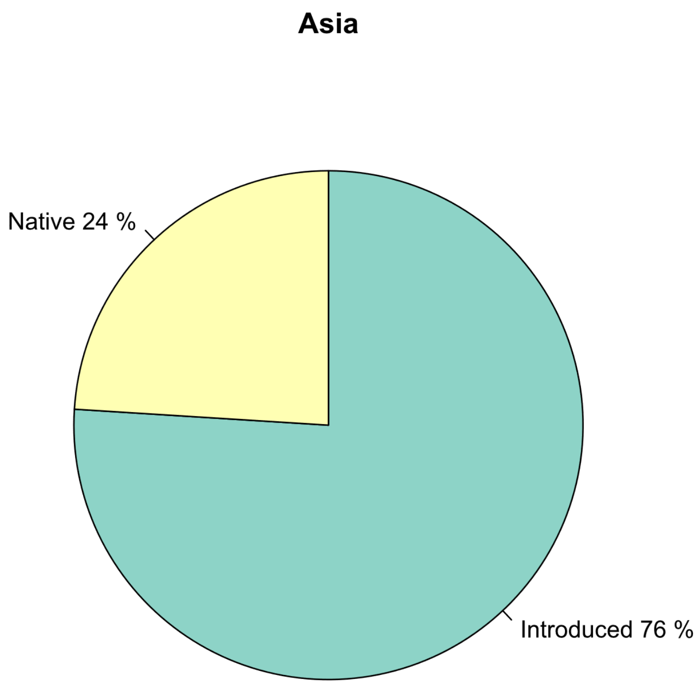

Fig. 4.5. The species that were found to be used as pets in Asia.

In the Fig. 4.5 It is shown which of the 37 species that were found to be captivated as pets in N. America, live in their native environment or it is a non-native continent for them.

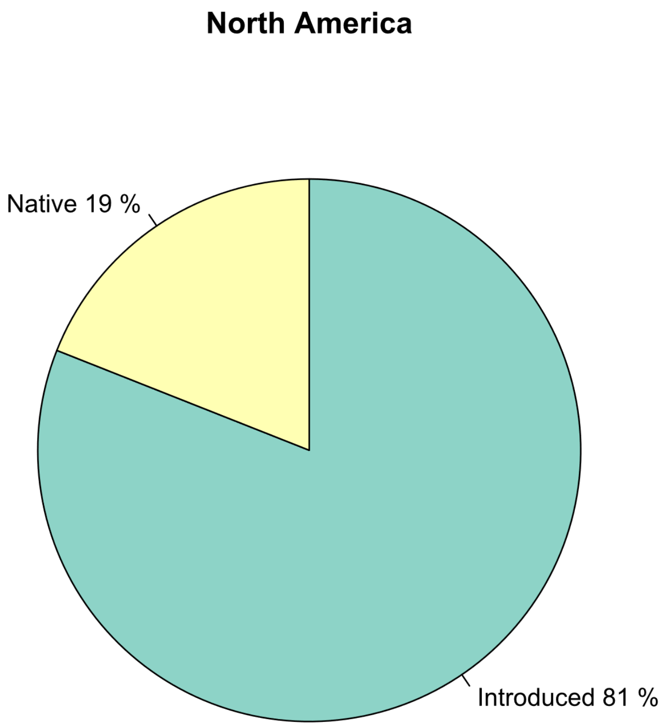

Fig. 4.6. The species that were found to be used as pets in N. America.

In the Fig. 4.7 It is shown which of the 7 species that were found to be captivated as pets in S. America, live in their native environment or it is a non-native continent for them.

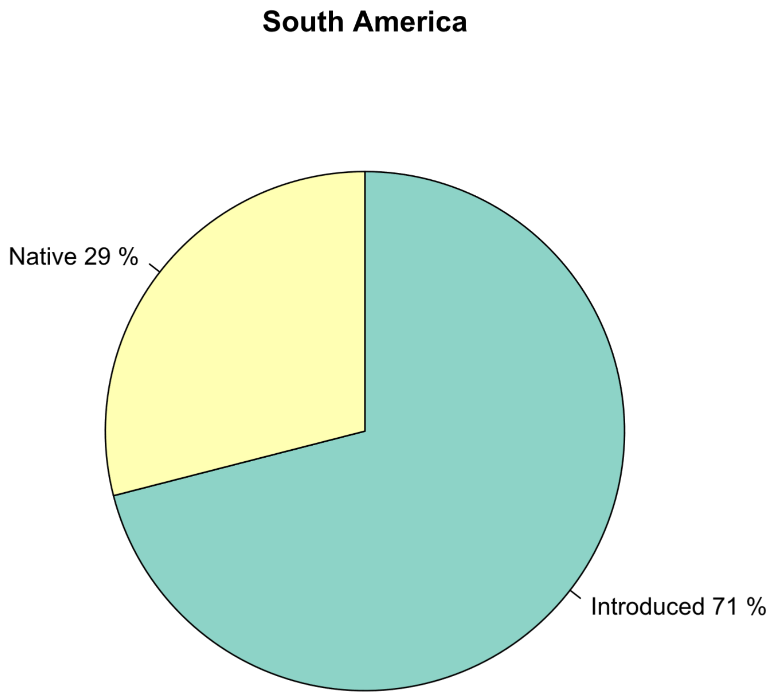

Fig. 4.7. The species that were found to be used as pets in S. America.

The species that live as pets in Australia are all in their native environment, on the contrary, Europe’s and Africa’s freshwater megafauna pets were found to be alien.

USA is the country with the most records from the social media platforms and it is important to look into the most popular platform for freshwater megafauna pet owners, meaning the numbers of records on Facebook, Twitter and Instagram.

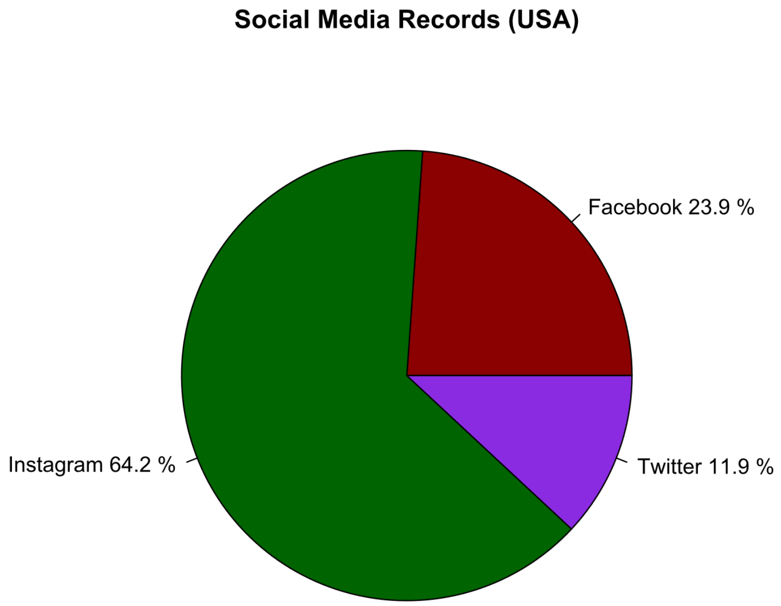

Fig. 4.8. USA's social media records according to the platform they were derived from.

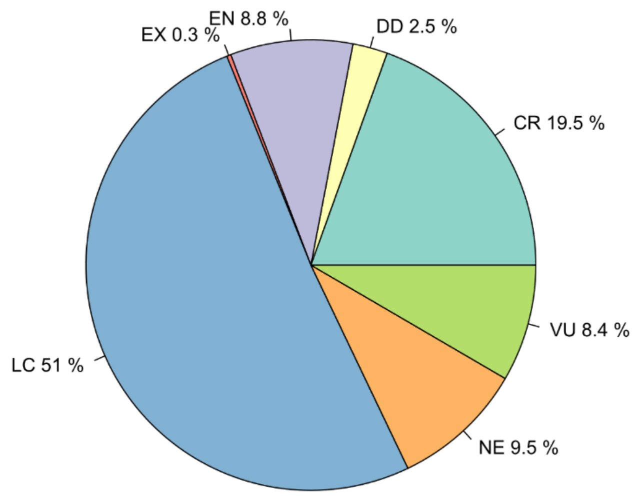

Fig. 4.9. The percentage of the threatened freshwater megafauna species that were found to be kept as pets according to the IUCN categorisation (IUCN, 2022).

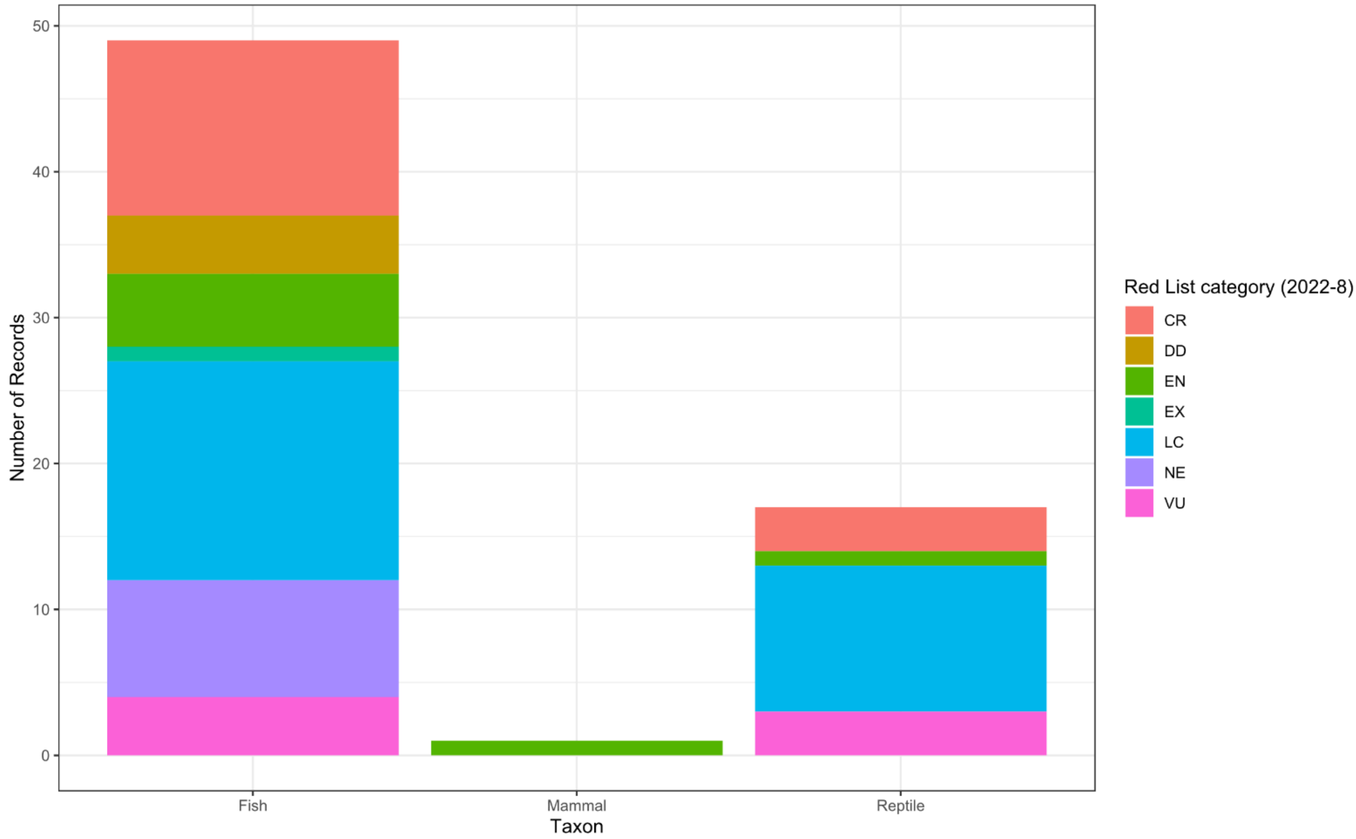

Fig. 4.10. Representation of the IUCN Red List categories for every taxonomic group of the pets that were located in relation to the records for each category (IUCN, 2022).

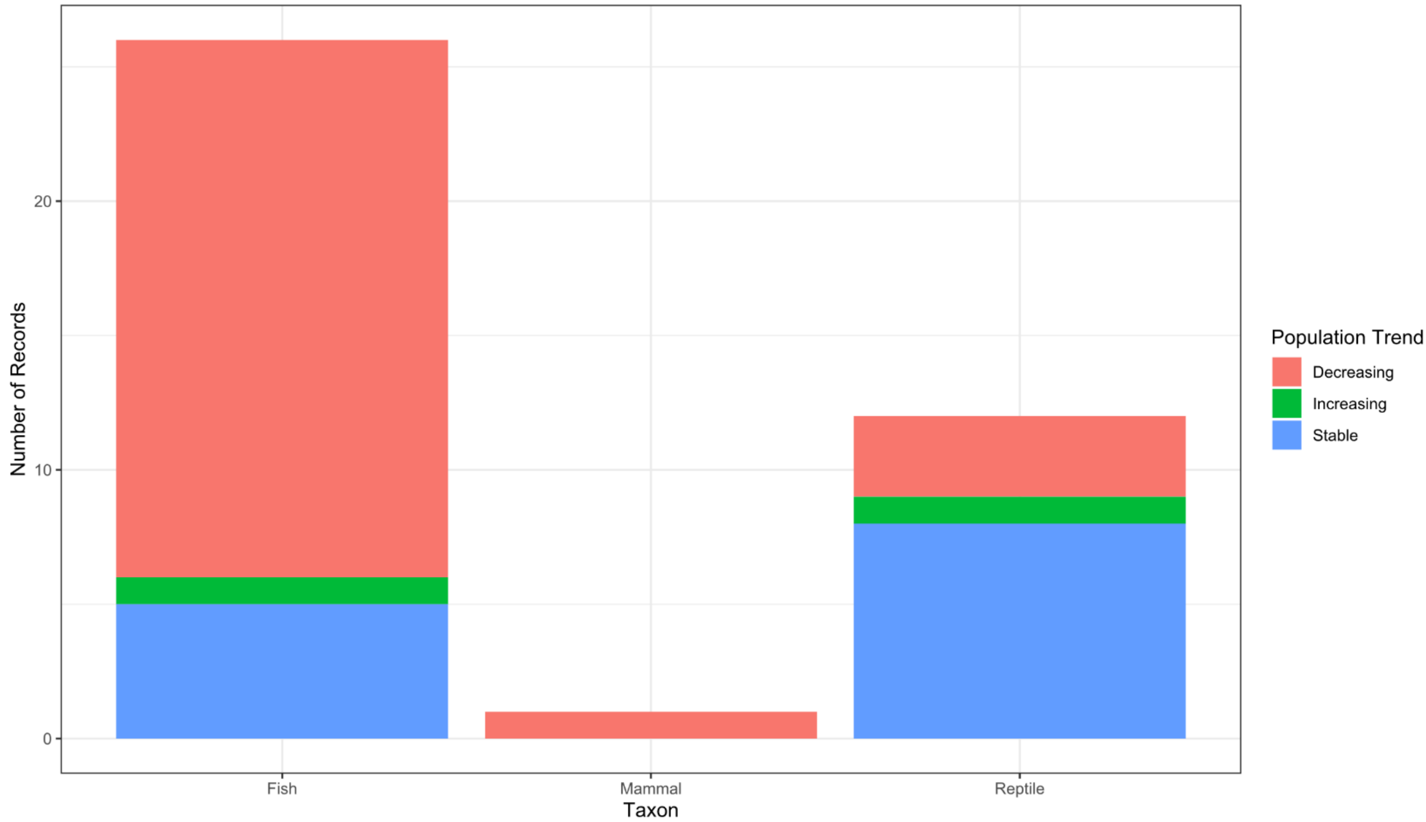

Fig. 4.11. Representation of the population trend for each taxonomic group of the recorded pets (IUCN,2022).

Table 4.5. This table consists of all the freshwater megafauna pets that were recorded and are listed on CITES and the list of threatened species on IUCN(CITES,2022, IUCN,2022).

Acipenser baerii	Eunectes murinus
Acipenser fulvescens	Eunectes notaeus
Acipenser gueldenstaedtii	Huso dauricus
Acipenser schrenckii	Huso huso
Acipenser sinensis	Macrochelys temminckii
Acipenser stellatus	Neoceratodus forsteri
Acipenser sturio	Nilssonia gangetica
Alligator mississippiensis	Orlitia borneensis
Alligator sinensis	Osteolaemus tetraspis
Amyda cartilaginea	Paleosuchus palpebrosus
Apalone ferox	Paleosuchus trigonatus
Arapaima gigas	Polyodon spathula
Caiman crocodilus	Potamotrygon motoro
Caiman latirostris	Probarbus jullieni
Crocodylus niloticus	Psephurus gladius
Crocodylus porosus	Pteronura brasiliensis
Crocodylus siamensis	Scaphirhynchus albus

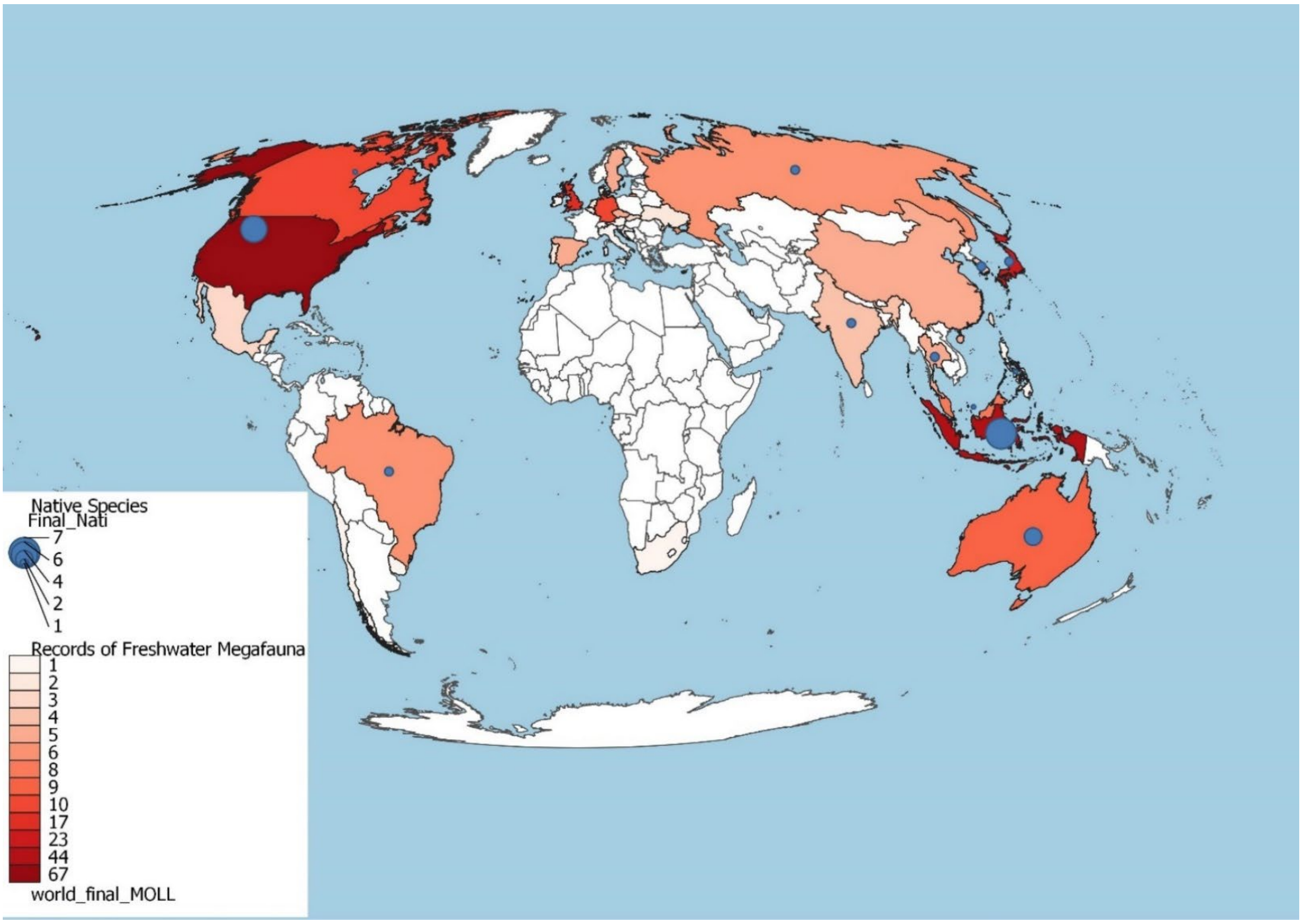

Fig. 4.12. Native freshwater megafauna species per recorded pets.

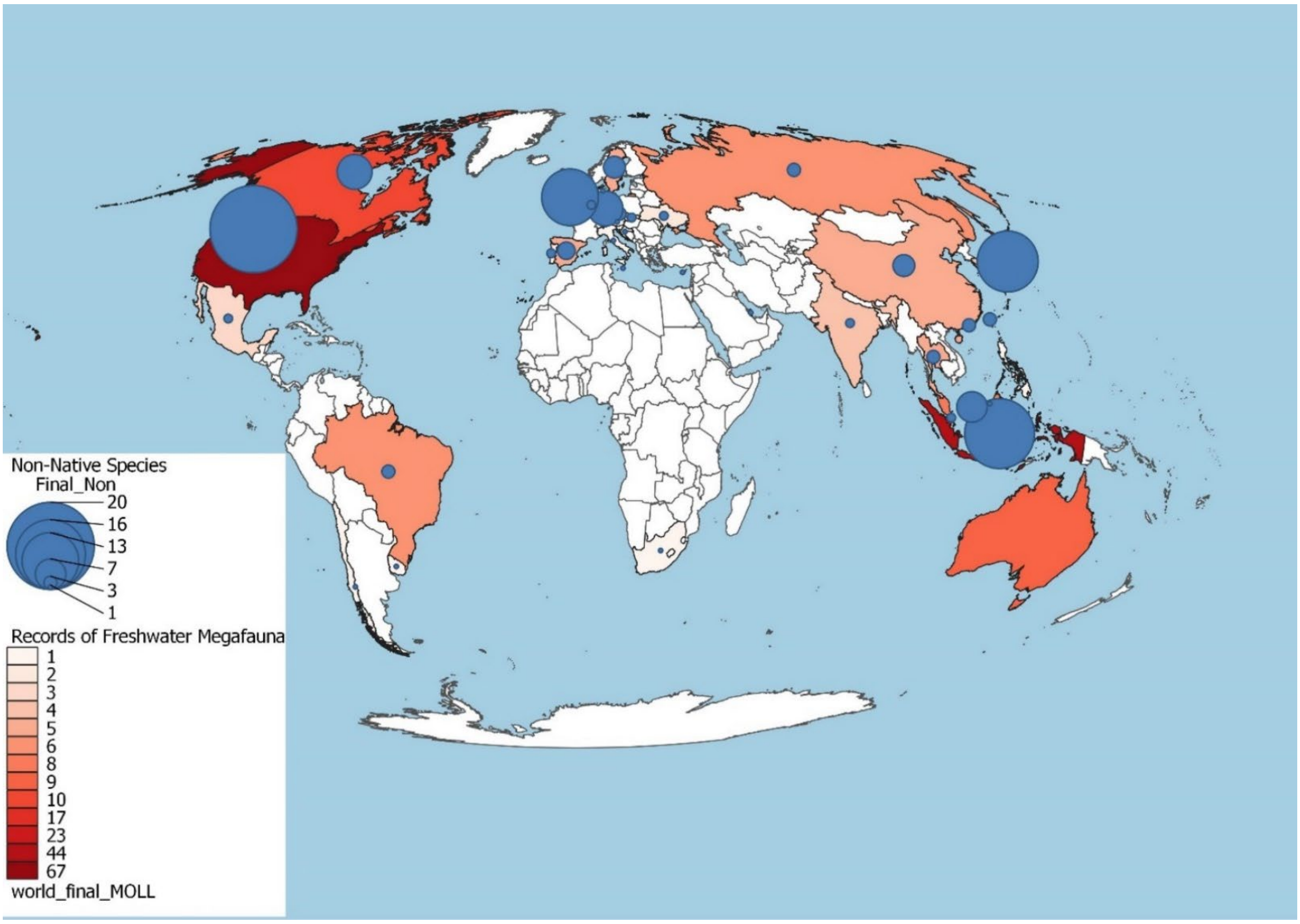

Fig. 4.13. Non-native freshwater megafauna species per recorded pets.

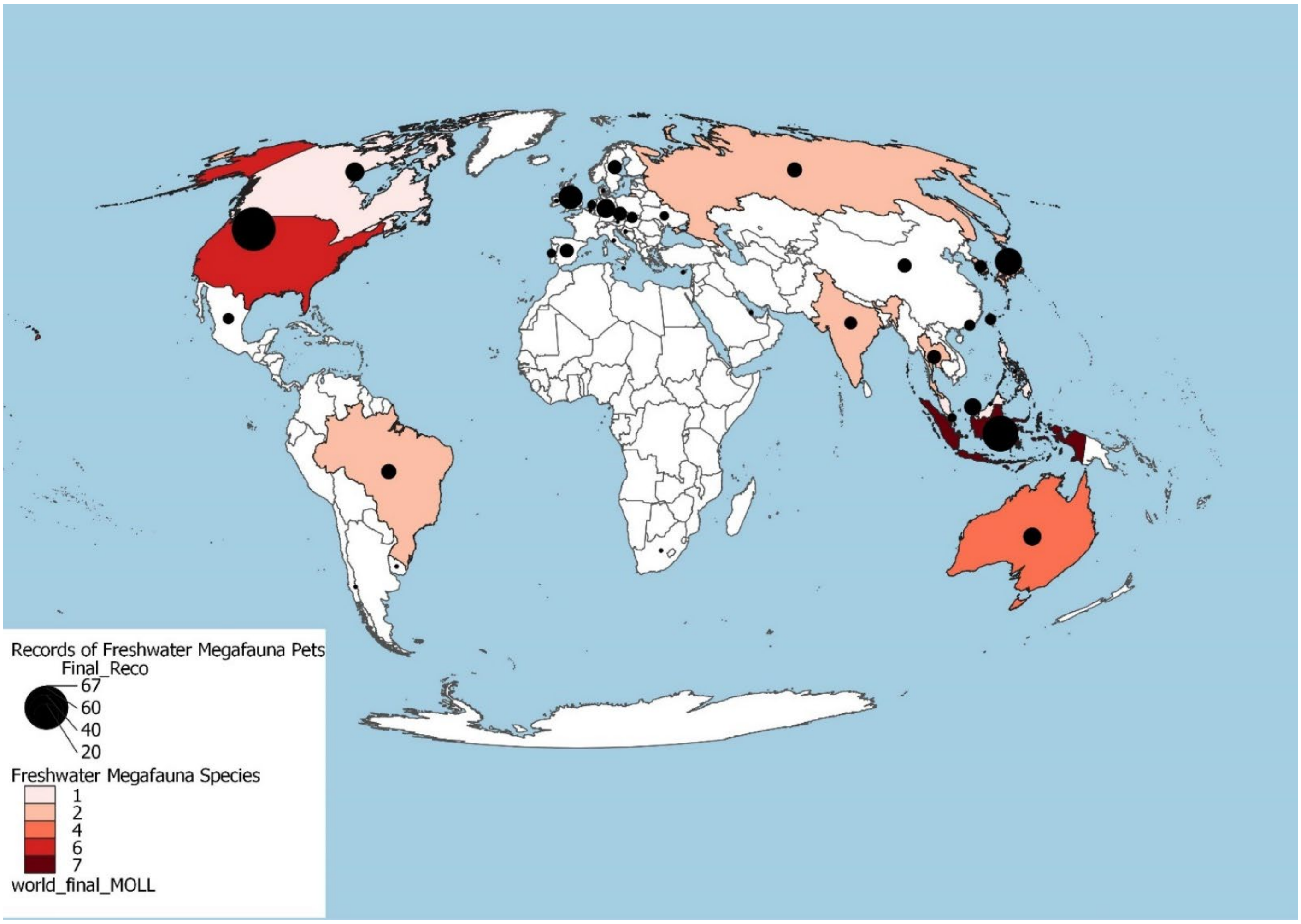

Fig. 4.14. Recorded pets per freshwater megafauna species (IUCN,2022).

Table 4.6. EICAT framework on the recorded freshwater megafauna pets according to the range where they are alien (IUCN,2022).

Binomial Name	**Taxon**	**Alien range**
Caiman crocodilus	Reptile	Cuba, Thailand, Puerto Rico, USA
Channa marulius	Fish	USA
Clarias gariepinus	Fish	Africa, Argentina, Bangladesh, Brazil, Cambodia, China, Cote d' Ivoire, Cyprus, Czech Republic, France, Gabon, Hungary, India, Indonesia, Iraq, Jordan, Lesotho, Malaysia, Myanmar, Nepal, Netherlands, Philippines, Poland, Russia, Singapore, Slovakia, South Africa, Thailand, Turkey, Vietnam
Ctenopharyngodon idella	Fish	Afghanistan, Algeria, Albania, Argentina, Armenia, Austria, Azerbaijan, Bangladesh, Belarus, Belgium, Bhutan, Bolivia, Brazil, Brunei Darussalam, Cambodia, Canada, Colombia, Costa Rica, Cote D'ivoire, Croatia, Cuba, Cyprus, Czech Republic, Denmark, Egypt, Estonia, Ethiopia, Fiji, Finland, France, Germany, Greece, Guyana, Honduras, Hong Kong, Hungary, India, Indonesia, Iran, Israel, Italy, Jamaica, Japan, Kazahkstan, Kenya, Korea, Kyrgyzstan, Laos, Latvia, Malaysia, Mauritius, Mexico, Moldova, Mongolia, Morocco, Mozambique, Myanmar, Nepal, Netherlands, New Zealand, Nigeria, Pakistan, Panama, Peru, Philippines, Poland, Puerto Rico, Reunion, Romania, Rwanda, Serbia and Montenegro, Singapore, Slovakia, Slovenia, South Africa, Sri Lanka, Sudan, Sweden, Taiwan, Tanzania, Thailand, Tunisia, Turkey, Turkmenistan, Ukraine, USA, UAE, UK, Uruguay, Uzbekistan, Vietnam
Lates niloticus	Fish	Cuba, Lake Victoria, USA

Chapter 5

Discussion

5.1 Discussion

In recent years, a trend has emerged where people share pictures of their exotic pets on social media. The owners take pleasure in exhibiting their one-of-a-kind pets to the world, and social media offers an easy way to do that. These photos are captivating, displaying the remarkable species and the extraordinary connection that can develop between humans and animals. In the research carried out in this dissertation, the results demonstrated that the social media platforms allow traffickers and pet owners to create private groups, pages, or accounts where they can share photos and videos of the wildlife and their products. Instagram is the most frequently used social media platform through which, freshwater megafauna owners wish to present their exotic pets to the public, from the day of their acquisition or adoption to the everyday life with them and the difficulties or achievements and their features or skills development. The differences in the numbers of the results are remarkable since Instagram occupies 87% of the records, while Facebook 10.4% and Twitter only 2.6%. This shows clearly a preference of the freshwater megafauna pet owners on the platform of Instagram. This is a valuable outcome, due to the fact that the results of this type of research were based principally on this order of prioritisation of the platforms. However, it contradicts the statistics, since the most widespread platform is Facebook. On the other hand, East Asia is the region with the most users, but America provided more data to complete the database. More specifically and answering the first research question of this dissertation, the countries that were found to have the most records of the specific list of the total number of 67 freshwater megafauna species and their possession of them as pets are: the USA with 67 records, the second country in the row is Indonesia with 44 records, the third is Japan with 23 and in the next 3 places that are worth noting are: the United Kingdom, Canada and Germany. This, of course, does not only draw conclusions about countries' social media usage rate, but also about their interest in freshwater species of the specific size range. Moreover, the country with the most records has a considerable differentiation in the part that every social media platform is occupying in the database with smoother shifts between them. More specifically, Instagram occupies almost the 64% of the records, 24% is occupied by the Facebook posts and almost 12% includes Twitter publications. Another interesting factor to look into is the taxonomic group (mammals, fish, reptiles, amphibians) which the pets belong to. The numbers showed that the species which are mostly used as pets are fish, followed by reptiles and mammals. From the total number of 67 species, 50 were fish, 15 were reptiles, 1 was a mammal, while no amphibian species were recorded as pets. The records of the freshwater megafauna pets have similar results with 240 records for fish, 131 for reptiles, 1 mammal and no records for the amphibians. The fact that there was only one mammal species found to be kept as a pet is a biased result and cannot represent any conclusive results for its category in this dissertation. Comparing to the amphibians which include only two species and there were consequently no pets found through the social media research. In comparison to references, the biggest part of threatened megafauna species are mammals and then fish, but this is also a matter of high exploitation of fish for consumption that leads to their extinction (Ripple et al., 2019).

From the 67 freshwater megafauna species, there is a significant interest to investigate which ones face a great threat on their populations and which not. Therefore, the results of the research indicated that there are 12 species for which there is not enough information or not available data but for the rest of species, 37% is under threat, while 1 species is already extinct. The rest of the species are at a lower risk with 51%. However, it is acknowledged that the megafauna species are at higher risk than other vertebrates and freshwater megafauna is in higher risk proportion than other ecosystems (Ripple et al., 2019). It is considered significant to have a direct comparison between the two taxonomic groups with most data which are the fish and the reptiles in terms of the continents that the pets have been located. Accordingly, there is much more fish than reptiles captivated in Asia, unlike the European citizen are apparently more interested in adopting a reptile as a pet than a fish. Small differences are marked in Africa and N. America, whilst S. America has slightly more reptile taxa pets. On the other hand, Australia was located as the continent exclusively for fish, as, according to the social media research, no reptiles nor mammals live as domesticated animals there. By identifying the locations where these species have been kept as pets, the second research question can be addressed.

By the same token, there is a necessity to search out what is the region where the freshwater megafauna pets live, in terms of being indigenous or alien. It has been determined that 76% of the total number of pets kept in Asia are introduced to the continent. There were similarities on the results and percentages for the continent of S. America whose pets are native by only 29% in relation to the introduced species. Similarly, 81% of N. America's pets are non-native. Interestingly, European and African citizens are owners only by alien species, in contrast to the Australian citizens who adopt pets that come from their own continent and are native. These findings provide answers to the third research question regarding the proportion of species that were considered exotic for the region in which they were identified as pets.

From the total number of pets, the majority is gathered in the category of Least Concern (51%), therefore, they are not considered as threatened. On the other hand, there is an interestingly high number of Critically Endangered species especially in the category of fish and then for the reptiles. Furthermore, the Endangered fish species are appreciably noticed, as well as an almost equal number of Vulnerable species from both taxonomic groups. Clear conclusions cannot be drawn for 44 records and 12 species due to insufficient information and data deficiency, leading to hesitation. It should be noted that 37% of the pets are threatened. From all the records and according to the Red List of IUCN, 67 species are listed, while 34 are on the CITES lists.

In addition, the population is a matter of investigation due to the high numbers of threatened species. Referring to the views of Fig. 4.10 most of the fish and together with the only mammal pet have a decreasing population trend. On the contrary, the populations for the majority of reptile pets are at stable level.

An equally significant aspect of the connection between the introduced and native region (continent) is the representation of the Chord Diagram where the flow shows the transferability of species between all continents. The strongest flow is obviously noticed for the Asian continent that its species are mainly transferred intracontinental and then to multiple continents. The second most significant flow results are starting from S. America to other continents and then from N. America to multiple locations worldwide. On close analysis, the majority of pets are transferred to multiple continents and regions.

Species invasions could pose economic risks to a state or more broadly to a continent. This is often difficult to determine concretely and accurately, but it is not yet easy to investigate this, as much as the financial burden that comes from natural disasters. In areas such as Australia, the cost of disasters from invasive species is extremely high, surpassing any other cost of natural disasters, such as earthquakes or floods (Turbelin et al., 2023).

When alien species are introduced through humans to new regions, the reasons behind this problem can be included in human activities of which trade plays an important role, either as a part of the food chain or as pets, as discussed in this dissertation. The economic risks that the industrial factor has to face are enormous and many times they are not taken seriously by the authorities, even though they can reach several billions dollars. The highest number of costs accumulate in the United States and then in China, Australia, Canada and India in the sectors of agriculture, fishery and forestry (Turbelin & Hudgins, 2023).

In addition to the damage to biodiversity, invasive species also cause significant damage to France's economy, according to research, costing more than 10,000 million dollars in the last 30 years (Renault et al., 2021) and Singapore with an ongoing tendency to increase (Haubrock et al., 2021).

The economic impact of the invasive species in Asia research highlights the importance of considering non-English language data to obtain a more accurate estimation of the significant cost difference associated with the acquisition of invasive species in Asia compared to South America, which also boasts rich biodiversity (Liu et al., 2021).

On the other hand, United States costs reach and surpass 1 trillion dollars the last 60 years, which is a really high number that is caused by thousand of non-native species living within its borders (Fantle-Lepczyk et al., 2022).

Upon comparing the data displayed on maps Fig. 4.12 and Fig. 4.13, it becomes apparent that the number of native pets is significantly lower than that of alien pets, and the geographical area covered by alien pets is also greater. This is answering the last research question of the dissertation referring to the geographic extent of the introduced pets. According to previous research and combining the information to the results, efforts to preserve the biodiversity of freshwater ecosystems can be significantly undermined by the trade of exotic pets. The big number of non-native species by introducing them to a new region, will create resource challenges for the native species, bring new diseases, alter the ecosystem and lead to extinction risk for the latter. The fish and reptile taxonomic group is particularly affected since most of the species that are introduced and kept as pets belong to this category. Soon, habitat fragmentation is expected to occur as a result of human-induced changes in water quality, vegetation, and the state of habitats. The degree to which regulations for the trade of wild pets are being adhered to remains unclear, especially in Asia, North America, and South America, which have a high proportion of alien pets. Non-compliance with regulations by countries can lead to overexploitation and illicit trade.

Given that Instagram is a predominantly visual platform that emphasizes the sharing of photos and videos, individuals might perceive that their exotic pets are intriguing and visually appealing, making them ideal for sharing on this platform. Furthermore, Instagram hosts numerous communities of pet owners who exchange knowledge and advice regarding their exotic pets, which encourages and inspires individuals to share their own content. Certain number of people might be reluctant to post photos of their exotic pets on other social media platforms like Facebook or Twitter, owing to privacy concerns. Instagram, however, empowers users to regulate who has access to their content, making it a more attractive option for sharing pictures of pets. Moreover, it has been discovered that fish are the primary taxonomic group that individuals prefer to keep as pets. This may be due to their relatively low maintenance needs compared to reptiles or mammals, such as not requiring outdoor walks or exercise, which caters to the busy schedules and extended working hours of pet owners (Andrews, 1990; Lockwood et al., 2019). They also require a specific space and diet but not a lot of space, or expensive meals and veterinary care and this makes it easier and cheaper for people to own a fish than a crocodile, for instance. Another contributing factor could be that pet shops and online retailers provide a wider selection of options for fish pets, including not only the pets themselves, but also their food and accessories (Andrews, 1990).

The popularity of exotic freshwater megafauna fish in Asia can be attributed to cultural and social factors. In some Asian countries, keeping an aquarium with fish is a longstanding tradition. Furthermore, the rise of the middle class in many Asian societies has made owning an exotic pet a status symbol (Mitchell, 2009; Sigaud et al., 2023).

The lack of information, uncertainty in taxonomy, scarcity of resources, and fast-paced alterations in freshwater habitats are some of the factors that collectively contribute to a significant proportion of freshwater megafauna species having unknown data in the IUCN database. The findings indicate that 37% of the pet freshwater megafauna species are currently under threat, implying a possible decrease in their population or degradation of their natural habitats. This situation could have significant consequences for their survival and the ecological well-being of freshwater ecosystems. Thus, it emphasizes the critical need for responsible pet ownership and sustainable management of freshwater resources.

Compared to reptiles or mammals, pets belonging to the fish taxonomic group are experiencing a more significant decline in their populations, indicating the presence of grave threats and challenges. This trend has serious implications for the health and functioning of freshwater ecosystems, given the crucial role that fish play in maintaining ecosystem balance and stability. Reptile pets have a more stable population trend and this means that the overall population is not experiencing significant growth decline and it is relatively stable over time. However, it is important to note that this statement may not apply to all species of reptiles equally and population stability may not necessarily indicate a healthy or thriving population.

5.2 Limitations

The use of social media platforms has become an increasingly popular method for researchers to gather data on various topics, including exotic animals (Carr & Hayes, 2015). However, extracting data from social media can be a challenging task that presents several obstacles. One of the main challenges is the time-consuming nature of the process, which involves sifting through large amounts of data to identify relevant information. Additionally, managing the research in a concise and well-organized manner is critical to ensuring accurate analysis. Failure to do so can result in inaccurate or incomplete data, which can lead to flawed conclusions (N. Johnson et al., 2022; Li & Suh, 2015).

Moreover, analysing large amounts of data can be overwhelming, especially when dealing with complex data sets. Researchers must use appropriate analytical tools and methods to analyse their data accurately. It is critical to ensure that data is representative of the overall population of exotic animals. As, for example, in the case of the taxonomic group of mammals, the fact that there was not enough data derived from the social media platforms could be a bias of the methodology and does not provide representative conclusions. However, social media data may not be representative of the entire population of exotic animals, as it is based on individuals who choose to post photos on social media. Some individuals may choose not to post photos of their exotic animals, resulting in a biased sample.

In addition to this, data in the database may not be complete, as users may not provide accurate information about the exotic animals they post. Furthermore, not all posts may include information on the animal's species, origin, or region where they are introduced, which can make it difficult to track their history. People may not accurately report their ownership of exotic pets, or they may be reluctant to do so. Moreover, some people may use social media to present a distorted image of themselves or their pets, which may not reflect reality (Li & Suh, 2015). These limitations must be considered when analysing data from social media platforms.

The collection and use of data on exotic animal species can also raise ethical concerns. It may promote the exotic animal trade, which can have negative impacts on animal welfare and conservation efforts. Researchers must follow ethical guidelines and acquire informed consent from participants to avoid any ethical issues. Additionally, privacy and data protection concerns associated with gathering data from social media platforms must be addressed. Researchers must ensure that they are following all relevant laws and regulations regarding data collection and usage.

Moreover, it may not be feasible for some researchers to conduct this type of research due to language or cultural limitations. This can limit the scope and applicability of the research findings. Therefore, researchers must acknowledge the limitations of their findings in social media research and refrain from making broad generalizations that may not be applicable to the wider population. The generalizability of such research should be carefully considered by the researchers.

To conclude, extracting data from social media platforms can be a demanding task that poses several challenges. Researchers must use appropriate analytical tools and methods to analyse their data accurately (South et al., 2022). The limitations associated with data collected from social media platforms must be considered, and researchers must follow ethical guidelines and acquire informed consent from participants. Language and cultural limitations may also limit the scope and applicability of research findings (Angulo et al., 2021). Researchers must acknowledge these limitations and refrain from making broad generalizations that may not be applicable to the wider population. Overall, careful consideration and proper management of data extracted from social media platforms are essential to ensuring accurate research findings.

5.3 Conclusions

Over the past few years, social media platforms have become a significant avenue for the wildlife trade. Wildlife traffickers leverage social media to promote their products/animals, engage with prospective purchasers, and conduct transactions. Freshwater megafauna species as flagship species have a special interaction with man, who is either interested in their possession due to their unique features, or to protect them by giving importance to the investment of time and money for their conservation. It is important to recognize that owning exotic pets ethically and responsibly is not always the case. Some exotic animals are captured from their natural habitats and illegally traded as pets, which can result in the exploitation and endangerment of wild populations. Furthermore, certain exotic pets require specific dietary, environmental, and medical care that can be challenging to provide in a household setting.

A comparative example of how captivating is the freshwater megafauna for some people, could be the existence of zoos and parks with animals, which usually host rare and wild animals and have a high number of visitors since they attract the interest of groups of all ages, social or economic status and educational level. Such an experiment was carried out, identifying how many visitors wanted to see the rare species despite the difficulties, as well as risked observing them, and this confirms the interest of the world in rare species (Angulo et al., 2009). Endangered species are available in the legal trade and are already causing negative impacts on their populations. Illegal trade, however, involves an uncontrolled number of wildlife trades and therefore could be considered an even greater threat. Interestingly, many Internet users who have an account on social networking sites, provide photos and information about their exotic pets, creating groups which include hobbyists and traders, and this could indicate how organized the advertising and trading of such animals through these platforms. The transfer of a species in a natural way or with human help, serves the biogeographical expansion in new areas, overcoming every limit and border, conquering or even influencing the new environments that host them. It will certainly be necessary to give a basis to the differences that may have the way the invasion took place. On this subject, it is argued that the only changes brought about by any species invasions are the differences in the configuration of the species and in particular the ecological challenges that come about because of them (Hoffmann & Courchamp, 2016). When endangered species are exploited by consumers or collectors, then this can lead to their complete disappearance. The aim of this dissertation is to raise awareness of freshwater megafauna species and to increase techniques related to their captivation and use as pets, with the ultimate goal of reducing the number of endangered species and educating the public about the dangers of owning such an animal.

5.4 Suggestions

As this research indicates, gaps in literature, research and data reflect a lack of awareness and knowledge in freshwater megafauna and the impacts and threats they face. In this way the needs for impact assessment and biosecurity are highlighted. The results clearly state the need to implement prevention efforts and surveillance strategies. People often feel that their social status is improved when they acquire products or animals that are generally scarce for the area in which they live and that their acquisitions show how strong they are mentally, financially and socially. Demand increases production, and directly affects the supply and cost of the good. Freshwater biodiversity conservation policies to reduce the interest in acquiring an exotic pet, becoming a method of avoiding the announcement of information related to the degree of rarity of certain animals, however, this predisposes to risks of losing investments for the protection of these species. Appealing to the consumer's morality could affect their level of need and reduce the allure of rarity in an animal. Restraining trade would not be an effective solution since such restrictions increase illegal trade, which reinforces the reduction in data access.

To enhance the prevention of illegal wildlife trade, governments ought to reinforce their laws and regulations related to it while intensifying the penalties imposed on those who engage in such activities. Additionally, law enforcement agencies must receive proper training to efficiently detect and prevent illegal wildlife trade.

Raising public awareness is crucial to educate people about the significance of freshwater megafauna species and the adverse effects of wildlife trafficking on these species. Social media, public events, and various media channels can be utilized to initiate public awareness campaigns.

To ensure the legality and sustainability of trade in freshwater megafauna species, it is recommended that governments regulate and monitor it. This can be achieved by implementing permits and quotas, as well as mandating the use of tracking and identification technologies.

The reason why some individuals turn to unlawful wildlife trade is due to the absence of other income opportunities. To address this issue, governments and conservation groups can facilitate the creation of sustainable livelihoods for nearby communities, such as promoting ecotourism and sustainable fishing practices.

Working in partnership with international organizations such as CITES can promote sustainable and regulated trade in freshwater megafauna species. To combat the illegal trade of wildlife, governments can also collaborate with non-governmental organizations and other entities to exchange information and resources.

The preservation of endangered freshwater habitats is vital for the preservation of their species. Governments may establish safeguarded regions and strive to rehabilitate deteriorated habitats to sustain these species.

Gathering data is one of the most challenging tasks when conducting research on social media. Researchers may encounter the need to utilize web scraping tools to gather data from different social media platforms, which can be both technically challenging and time-consuming. Such tools are: Octoparse (Twitter, Facebook, LinkedIn), Social Media Miner (Twitter), Netvizz (Facebook), Brandwatch (Instagram, Facebook, Twitter).

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