THE GLOBAL TRADE IN CHAMELEONS FROM A BIODIVERSITY HOTSPOT

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Contents

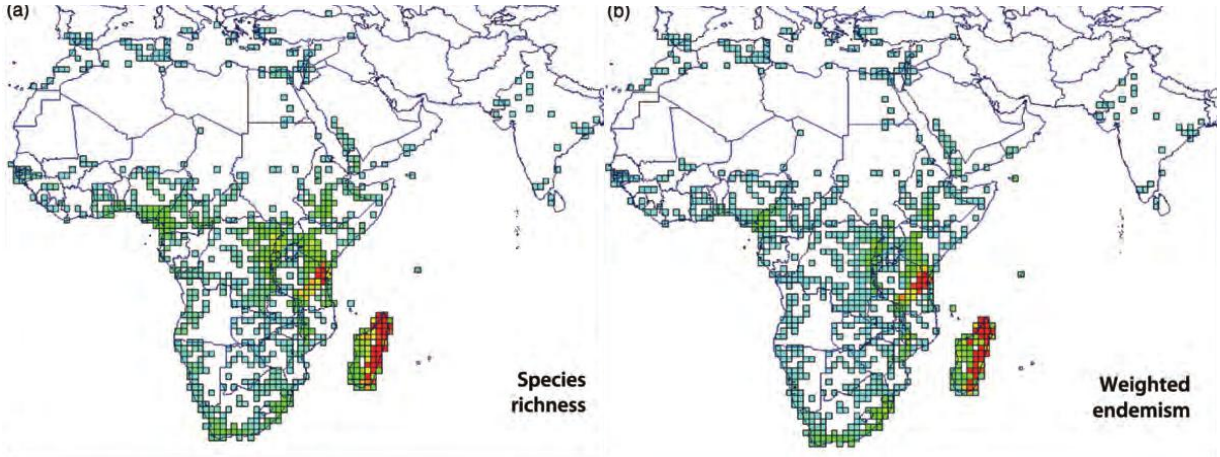
Abstract

The current global trade in chameleons is reviewed and the scale and nature of the threat posed to chameleons globally by trade is assessed. As an under researched genera with high levels of endemism this study was essential in updating our current picture of chameleon conservation globally. This was done by analysis of the CITES global trade database combined with online trade analysis and on-the-ground research which surveyed sourcing in the largest global exporter of chameleons, Tanzania. 40% of the chameleons exported from the world's largest exporter during the study period were endemic range restricted species, this study also found substantial evidence that the impact of trade on endemic species could be much higher than indicated by the CITES data. This research revealed the scale of misidentification of cryptic animals such as chameleons in the CITES trade database and how this has large implications for conservation of threatened reptiles not just in Africa but globally. It identified a shift to more captive breeding in the market and how this impacts the conservation of endemic and range restricted species more highly than generalists. Other findings included the inadequacy of permit systems, mortality of chameleons in transit through the market and the misinformation amongst end consumers in the reptile trade. The potential of sustainable chameleon ranching is discussed.

Introduction

Chameleons are confined to Africa and southern Europe, with a centre of endemism in East Africa – especially Tanzania (Tolley & Herrel, 2013, p210). IUCN currently classifies 36% of chameleon species as vulnerable and endangered (IUCN, 2020). Multiple factors are involved in the loss of chameleons from the wild, these include habitat clearance, habitat fragmentation, climate change and collection for the international pet trade (Meng et al, 2016; Carpenter et al, 2005; Patrick et al, 2011).

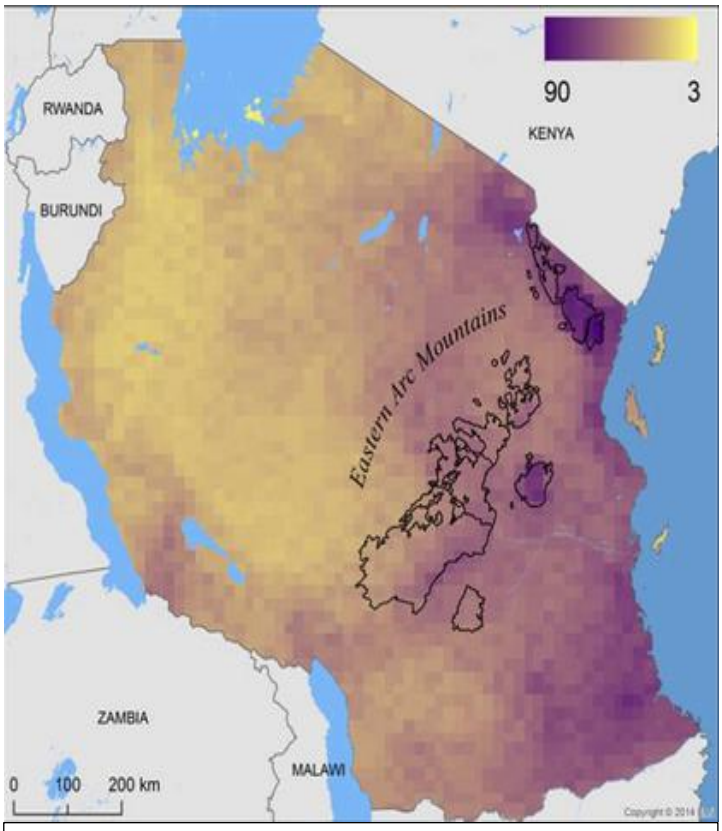
Chameleons are thought to have evolved in Madagascar and migrated around 70-80 million years ago across the Mozambique channel to mainland Africa (Tilbury, 2010). After arriving in East Africa they radiated into multiple lineages and hotspots of diversity appeared in South Africa, Cameroon and Tanzania. In Tanzania this pattern of diversity is intricate and is the product of multiple fluctuations in climate and rainforest cover repeatedly linking and isolating Eastern Arc montane regions (Burgess et al, 2007; Tolley & Herrel, 2013, p210). Current assessments place Tanzania as second only to Madagascar in chameleon diversity (Tilbury, 2010) with 41 species occurring in Tanzania (IUCN, 2020). However recent research has suggested the Eastern Arc mountains are underassessed and may contain higher levels of endemism and be of greater biological value than previously assessed (Rovero et al, 2014).



Maps of Africa's chameleon diversity in species richness and weighted endemism (Toley et al, 2013)

Globally it is the biodiversity-rich countries which are the source of wildlife for the exotic pet trade with the volume of exported products correlating with a nations levels of species endemism, species richness, IUCN threatened species, and the country's size (a proxy for habitat diversity) (Olsen et al. 2019). Consumers by contrast are mainly located in Europe, North America and Eastern Asia (Olsen et al, 2019). Trade from these biodiverse nations has oscillated and whilst there have been general trends, such as a widespread decline in legal trade of CITES appendix II species 2001-2012, these trends are dominated by a few key pet species (green iguanas, pythons and turtles) which can be hit by new regulations and other market forces producing trends that are not indicative of the diversity of trade in reptile species (Robinson et al, 2015).

Global trade in reptiles is becoming more thoroughly understood and we can see some patterns across reptile trade as a whole. The trade in reptiles is the second largest behind that of plants and consists mainly of skins for the fashion trade and live animals as pets.



Reptile species richness in Tanzania, Meng et al, 2016

Since the start of recording the origin of individuals in trade regulated by the international CITES convention (wild caught captive reared etc) there has been trends across all taxa, including reptiles, towards captive sourced products (Harfoot et al, 2018). One of the main factors to be considered when assessing the potential vulnerability of a reptile species to the impacts of wildlife trade is whether the species involved are utilised in the pet trade, which is estimated to form the majority of the trade in live reptiles both legal and illegal (Auliya et al, 2016). Looking at the regional patterns of the global reptile trade Mesoamerica was the largest exporting region, closely followed by sub-Saharan Africa then South America, South and South-East Asia, and West and Central Asia (Robinson, 2015).

Research on the sources of reptiles in the pet trade shows, there has been a general decrease in wild caught reptiles and an increase in captive bred and ranched reptiles (Harfoot et al. 2018). This may initially seem a good thing as captive breeding may ease pressure on wild populations, however it also has economic implications on rural communities and can be detrimental if loopholes allow wild reptiles to be exported as ranched and captive bred individuals. Given the reported shift from wild to ranched reptiles, more information is required on the benefits and impacts of commercial ranching operations for traded reptile species (Robinson et al, 2015).

Our current knowledge of the reptile trade is broadly based on research into the legal trade of CITES listed species. The illegal trade in reptiles is much harder to map due to the methodological challenges (Gavin et al, 2010) even the most conservative estimates point to illegal trade amounting to 10 times the volume of legal trade, but for some reptile species it may be closer to 100 times the volume of legal trade. (Schoppe, 2009). This lack of knowledge of the illegal trade can be especially damaging to conservation initiatives,

frustrating efforts to construct sustainable harvest goals which must be created using accurate knowledge of the current harvest effort.

Furthermore our picture of the global reptile trade is dated as very little research exists on the role of the internet and e-commerce in the global trade of reptiles, particularly for the pet trade. The use of social media and other online trade outlets to sell both listed and non-listed CITES species of many taxa has in recent years been shown to be of increasing global concern (Sajeva et al, 2013; Vaglica et al, 2017). It has been shown that social media is used increasingly in black market sales and has proven adaptable in avoiding detection (Xiao, 2017) This trend towards an increased influence of the internet over endangered species is also seen in reptiles (Morgan and Chng, 2018) and online marketplaces seem to be important outlets for African reptiles (Jensen et al, 2018). These reports show the difficulty in even approximating the influence of e-commerce on endangered species globally and very little work focuses on the dynamics of specifically the pet trade, indeed the internet as a both as a point of sale as well as a driving force behind trends in exotic pets is poorly understood (Bush et al, 2014).

Whilst there are these trends in reptiles as a whole chameleon trade is much less clearly understood. The last major review was published in 2004 by Carpenter and others and identified the following at the time of writing:

- African countries accounted for 96% of reported exports
- Madagascar, Tanzanaia and Togo dominated the export trade
- The 8 most popular chameleon species dominate the trade (*Chameleo senegalensis, Trioceros jacksonii, C. dilepis, C. gracilis, Furcifer lateralis, F. pardalis, T. hoehnelii* & *Kinyongia fischeri*)
- None of the remaining 96 species contribute more than 3% to the global trade.
- Madagascar and Tanzania distinguish themselves as having both high exports and high diversity of exported species
- High exports in the late 1970s declined, with the exit of Kenya from the trade, with a record low of approximately 3000 individuals in 1982, before rising again to record exports of 81,000 individuals in 2001.
- Reported captive bred and ranched individuals form a small but increasing contribution to the trade.
- In the 1990's national and international legislation has been successful in regulating the reported exports from the dominant exporting nations
- There is a continuing rise in demand
- Rise in demand has been satisfied by an increase in exports from other countries, in particular, Uganda, Benin, Mozambique, Yemen and Comoros. (Carpenter et al, 2004)

This review still leaves many things unanswered and over the 15 years since its publication there have been gigantic global shifts in the architecture of the wildlife trade both legal and illegal, with an influx of more aggressive harvesting techniques across taxa, changes in taxonomy of chameleons, newly emerging and affluent markets and the increasing

importance of the online marketplace as well as the advent of cryptocurrencies which facilitate online trade.

Of the 8 most traded species identified in Carpenter's 2004 review 6 are species present in East Africa, or mainland Sub-Saharan Africa at large and yet the majority of research has been focused on Malagasy species. Even in reviews of Malagasy trade it is acknowledged that there is a growing trade in non-Malagasy species (Carpenter et al, 2005).

Additionally, despite not contributing significantly to global trade, capture of range restricted endemics could have biologically significant impacts, especially considering the many species that only inhabit the isolated eastern arc mountains of Tanzania (Rovero et al, 2014)(Toley et al, 2013)

Current research does not cover the present trade in chameleons and current management recommendations for chameleons are relying on data from 15 years ago. There are large gaps in our knowledge of the trade in chameleons from Tanzania, currently this fragmented knowledge is what trade quotas are built upon and as such these gaps must be filled

CITES assessments place only one species, *Brookesia permata*, in appendix I all other genera are listed in appendix II by whole genera. The distinction between the appendices is that Appendix I includes species threatened with extinction and prohibits trade specimens of these species except in exceptional circumstances. Appendix II includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid over-utilisation incompatible with their survival. As such this means managed trade in all chameleon species bar one is allowed under CITES regulation. This is at odds with current IUCN assessments of the *Chamaeleonidae* which categories 52 out of 202 species which are categorised as endangered or critically endangered. In depth investigation will help to provide greater insight into the threat posed by trade in these species and improve management of trade.

This thesis will accurately map out the trade in chameleons globally from the period 2000-2019 with special focus on East Africa as a source of these animals, to do this it will assess the global trade as reported in the CITES trade database, it will then focus in on trade emanating from Tanzania. To better understand the biological impacts and in-country trade system field interviews will be conducted in Tanzania interviewing villagers in the mountain blocks that endemic east African species inhabit. This fieldwork will illuminate gaps in our knowledge regarding how accurately the CITES database reflects harvesting effort, how many animals are actually being removed from ecosystems, where they travel from there and which species are in demand at a local level. Finally online marketplaces will be assessed to understand the extent of the licit trade in East African chameleons and how this may contribute to demands at harvesting level. Both the information gathered from the fieldwork and the online surveying will then be used to evaluate the CITES trade database and its usefulness in understanding, and effectiveness at managing trade in organisms such as this.

Methodology

CITES trade database

The CITES trade database was used to provide data on the global trade in chameleons. The trade database contains all reported international trade in CITES-listed taxa exported from, or imported by, CITES Parties (states that have joined the convention) this data is supplied to the database as part of each parties official annual report to the Convention with ~1m records of trade in CITES-listed species of wildlife being added annually. The CITES trade database currently contains over 7 million records of trade in wildlife and 50,000 scientific names of taxa listed by CITES. The database is managed by UNEP-WCMC on behalf of the CITES Secretariat. This data was supplied by UNEP/WCMC using the Species+ website.

There are currently 178 Parties to CITES. Each party must designate a 'Management Authority' which is responsible for issuing permits and compiling these annual reports submitted to CITES

The data was in the form of a comparative tabulation table and the data spans the period 2000-2018 (collated December 2018) however the data is only complete until 2016 as reporting operates at a delay to the global database. This is due to several factors including processing time both by in country authorities in collating the annual report and by CITES in compiling the yearly database additions which must be entered manually into the database. Additionally problems arise in late submission of annual reports, incomplete reports being submitted, and in some cases Parties failing to submit reports for several years because of internal problems, such as civil war, lack of personnel or resources. As a result of these reporting problems, the most recent year for which comprehensive trade statistics are available is normally two years before the current year.

The data contains reported import and export numbers from CITES parties, the parties trading and species being traded, 'trade term' (skins, live animals, derivative products, bones etc), in country source (wild caught, captive bred, ranched etc) and the purpose of the transaction (e.g. commercial or for scientific use etc). For this research only data on *Chamaeleonidae* was extracted from the database.

Field research in Tanzania

Within Tanzania research was conducted to establish the source of the animals reported in the CITES trade database as being exported. To do this semi-structured interviews were conducted with local villagers at various locations in Tanzania.

Survey locations

The Eastern Arc Mountains (EAM) are a series of mountain blocks situated in East Africa with its northernmost point beginning with the Taita Hills in southeast Kenya and successive ranges running southwest towards lake Malawi ending at the Makambako Gap (although this as a zoological barrier is debated (Menegon et al, 2015)). The EAM is also defined geologically and climatically. Geologically the Eastern Arc Mountains are the oldest in East Africa being formed at least 30 million years ago (which is why the more recent Mt Kilimanjaro is not included in the EAM). Climatically the mountains are characterised by rainfall generated from moisture laden winds that blown eastwards from the Indian ocean. (Burgess et al, 2007)

These geological and climatic features have combined to create rainforest in these regions which is very old, with periods of climatic change over the millennia successively drying and wetting the lowlands of East Africa, resulting in the EAM becoming stable refuges for species during periods of lowland dryness. This successive linking and severing of links between mountain blocks in the eastern arc resulted in species evolving along different ecological pathways resulting in the high levels of endemism across taxa that we see today

These high levels of endemism across taxa dictated that the EAM would be the most judicious region to survey in Tanzania as reptile diversity is centred on this region (Meng et al, 2016), and it is the area where the most endemic species of chameleon are found, hosting several hyper-endemic species, indeed chameleons are used as evidence for the refugia theory for the EAM chain.

The locations chosen were villages surrounding nature reserves and national parks in the eastern arc mountain chain. Three mountain blocks were chosen, the East Usambara in the north of Tanzania, the Uluguru in Morogoro Region and the Udzungwa in the south of the EAM chain. These three locations were chosen due to several factors; firstly their proximity to major population centres/potential markets/major highways; secondly each hosts species endemic to that mountain block, thirdly each area contained within it protected forest, either a national park or nature reserve. Within each mountain block a selection of local villages were chosen based on accessibility and local expertise, they are listed in table 1. More villages were targeted in the Udzungwa are as we wished to target villages near different protected areas, national park and nature reserve as well as wanting to survey villages surrounding the lowland Magombera forest which hosts a hyper endemic chameleon found only there (*Kinyongia magomberae*) to see if these factors may effect chameleon harvesting.

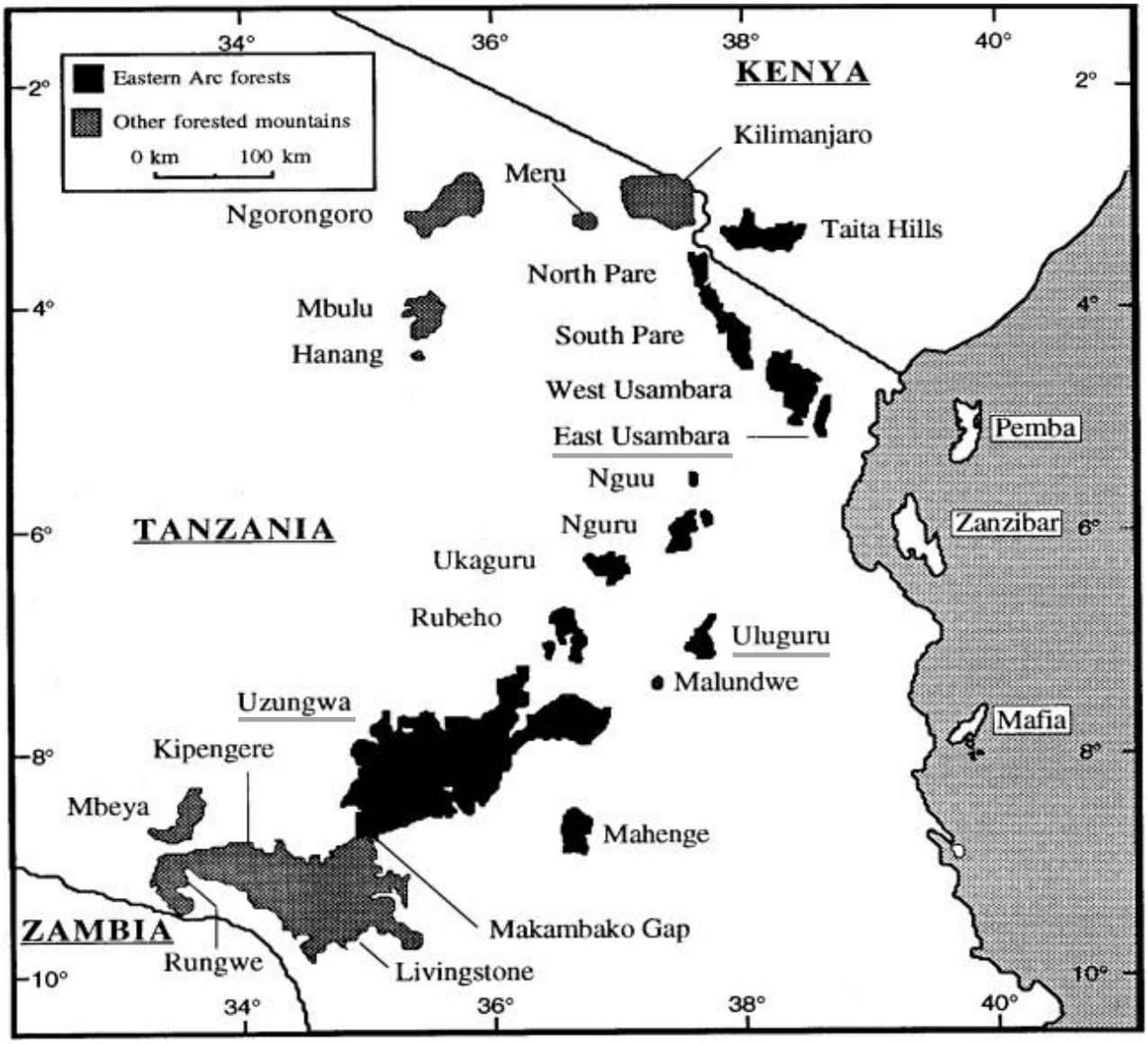


Figure 1: Map showing the 13 blocks of the Eastern Arc Mountains of Tanzania and Kenya. Survey locations underlined in green (map from burgess et al, 2007)

East Usambara	Uluguru	Udzungwa
Mbomole	Tchenzema	Sanje
Madizine	Bunduki	Sonje
Tabora	Vinile	Mangula
Mlesa	Nyandira	Kanenja (magombera)
		Katurkila (magombera)
		Mamwawala
		Ivanbu
		Kisege

Figure 1b: villages surveyed in each mountain block

The Interviews

Semi structured interviews were conducted with residents in the aforementioned locations. Interviewees were selected based on the expertise of local guides/foresters. People were interviewed both individually and sometimes in small groups where individual interviews

were not possible. A translator was used to ask the people the questions where they did not speak English (common).

The interview was roughly structured around the following questions:
- Are you aware of people selling chameleons around here?
- How often do you/they go and collect chameleons?
- How many do you/they collect?
- Are there particular types of chameleon you/they collect?
- Did you/they used to collect chameleons more or less than you do now?
- Are certain chameleons easier or harder to find now?
- Who do you/they sell the chameleons to?
- How much money do you/they get paid per chameleon?
- Do they buyers tell local people why they want the chameleons?
- Do you know anything about farming/ranching chameleons?
- To your knowledge is collecting chameleons legal or illegal?

In areas where the respondents had never heard of chameleon trade more broad questions were asked:
- Have you ever heard of or are interested in chameleon farming?
- To your knowledge is trading animals like chameleons legal or illegal?
- Is it possible people are collecting animals from inside the national park/nature reserve?
- Do you see chameleons more or less than you used to?
- Why do you think there are more/less chameleons?
- What kind of chameleons do you see?
- What is your opinion of chameleons
- Are other animals collected?
- Who are they bought by?
- How often do buyers come?
- Do the buyers tell you why they want them?
- When did they last come here?

Additionally these questions were occasionally asked as follow up questions to villagers that did know of the chameleon trade.

Additionally one interview was conducted with a middleman in the East Usambara which included more in depth questions due to his greater insight into the trade:
- How often do you get an order from [your agent in] Muheza?
- Do you go to many villages enlisting them in chameleon collection?
- How were you contacted initially by the agent in Muheza?
- What does the agent in Muheza want the chameleons for? (Use, destination etc)
- Were you told by the agent in Muheza that they had a permit, have you seen the permit?
- Is this in the past or is it still going on?
- Do you know what the agents do now they are not doing this?
- Has this business changed your life?

- Do you get paid per order or per chameleon?
- Do you make a profit between the collectors and the agent in Muheza?
- Does the agent request other animals? (snakes, birds etc)

Interviewing key informants in Tanzania

Casual interviews were conducted with people in Tanzania involved in fields with relevance to wildlife trade to get a better understanding of the wilder knowledge of the trade in academic circles, Non-Governmental organisations and government authorities

Online surveying

Online marketplaces were also surveyed to find which species are sold on the licit market, which species are in demand, and where possible how much individual chameleons were sold for. Conventional pet store websites, forums and social media pages were surveyed for chameleons and chameleon products.

Results

Global trends

Results from our assessment of the CITES global trade database show an overall decline in trade during the study period of 2000-2017 however this decline is predominantly only in the genera *Chameleo* with other genera remaining constant over this period (figure 2a). Sources for this global trade were assessed using two different metrics in the CITES data, regular export records and records where the origin was listed. As origin is only stated when the country of export is not the country of origin, this meant that the data on exports was used to show the trade in primary exports from the origin countries, whilst the origin data was used to infer the dynamics of the resale market of these animals. These two markets were significantly different, figures 2b & 2c illustrate primary exports, whilst figures 2d & 2e, based on trade records where the origin is listed illustrate the sources of chameleons re-traded from non-origin countries.

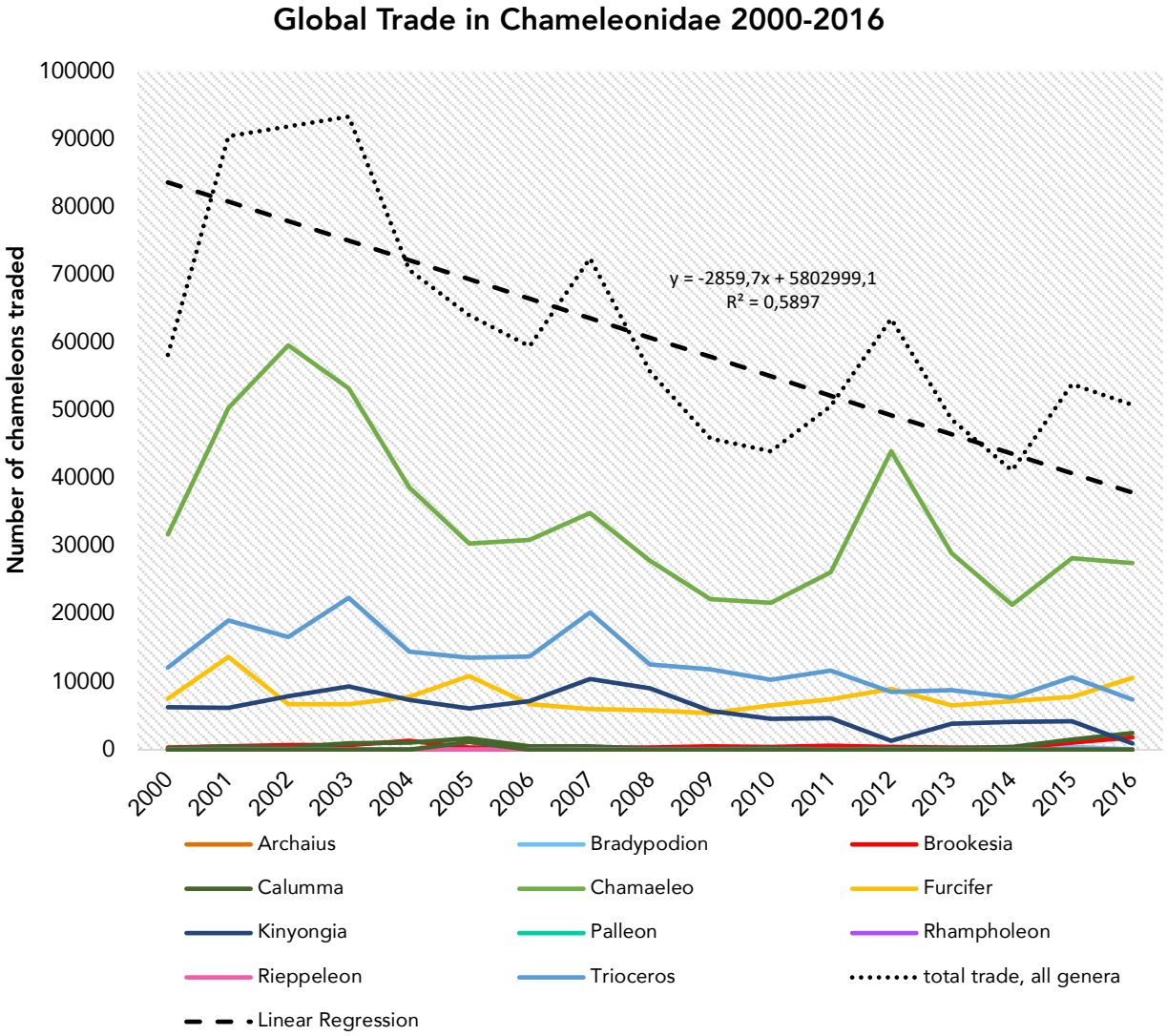


Figure 2a: The global trade in chameleons 2000-2016. Based on CITES data. A significant decline is seen over the study period p=0,00019827, however this is highly impacted by the trend in just the genus *Chameleo* over the study period the relationship between total trade and *Chameleo* was assessed using a regression analysis and was found to be highly significant p=0,0000000002, r^2= 0,92523744, as we can see the trend amongst other chameleon genera is much less dramatic with a negligible decline.

Primary trade

Looking at the primary export market (figures 2b and 2c) we can see that the top exporting countries are largely countries within the natural range of chameleon species (14 of the top twenty exporting nations). Of these Tanzania was the largest exporter by a wide margin (135,804 more chameleons traded than the next largest exporter Togo). Figure 2b shows us that although there is a high diversity in the origin of primary exports the destinations of these animals is much more homogenous, with the USA dominating imports, followed by a selection of smaller importers concentrated in Europe and East Asia.

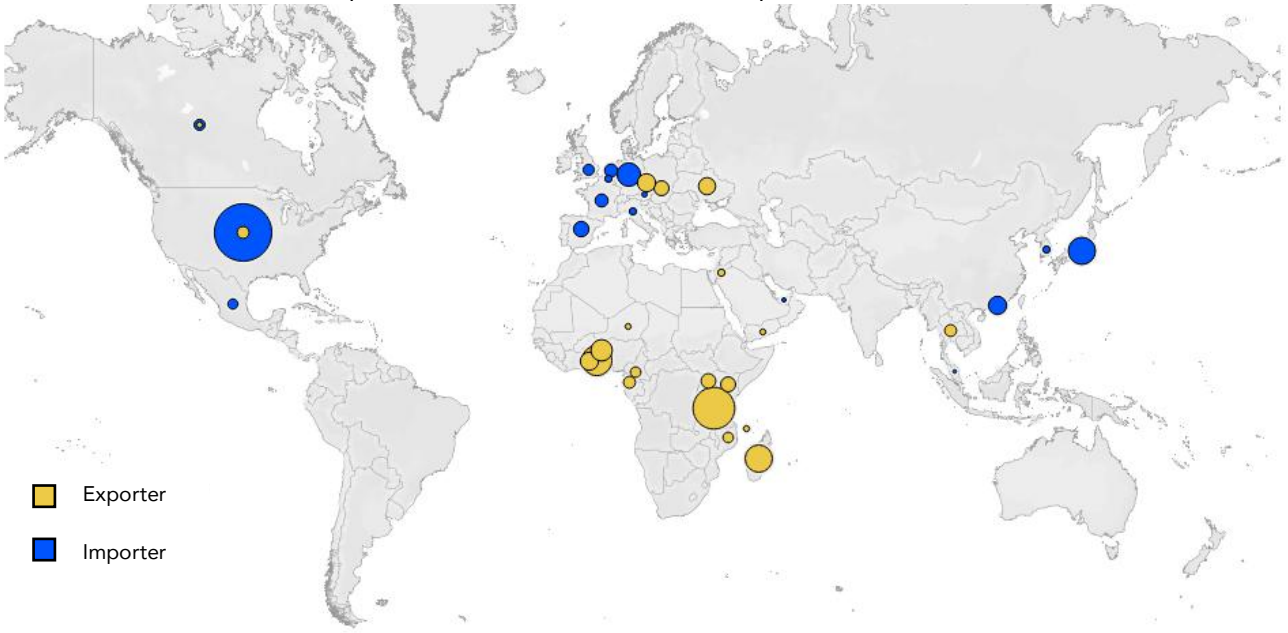


Figure 2b: A map depicting the top 20 exporting and top 20 importing countries for chameleons traded internationally, this represents the primary trade. generated using Tableau software inputting CITES data 2000-2017. Size of circle represents comparative volume of trade. Largest exporting country: Tanzania (280524 chameleons). Largest importing country: USA (533403 chameleons).

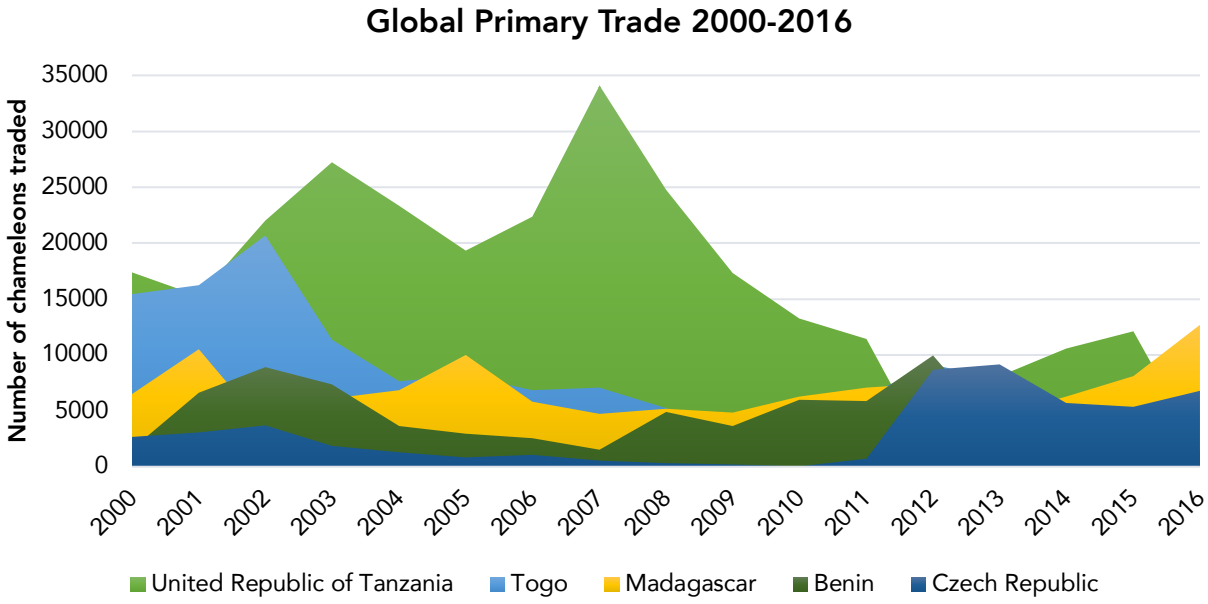


Figure 2c: Global primary trade over time, as we can see trade has been largely from Tanzania however this has declined from 2007, trade from Togo has also diminished over the study period. Trade from the Czech Republic has increased significantly from 2011.

The Global Re-trade Market

In the *Chamaeleonidae* the majority of exports are straight from the source country (1070367 chameleons) however there is still a large market in re-exports (67891 chameleons). The countries which report the largest re-export of chameleons are Ghana and the USA which function as the largest global hubs for these animals (figure 2e).

Research showed that the USA sources its chameleons for re-export from a cosmopolitan selection of predominantly African countries and Slovakia (20%). Ghana functions principally as a West African hub for export of chameleons, sourcing 86% of its exported chameleons from Benin, 7% from Togo, 6% from Mali and 1% from Niger; this greatly influences the data on sources of chameleons re-exported globally (figure 2d).

The destinations of these re-exports are shown in figure 2d. These chameleons in the re-trade market are exported to a variety of destinations, this is dominated by the USA, perhaps unsurprising considering the dominance of the USA as an importer in the primary export market as well (Figure 2b).

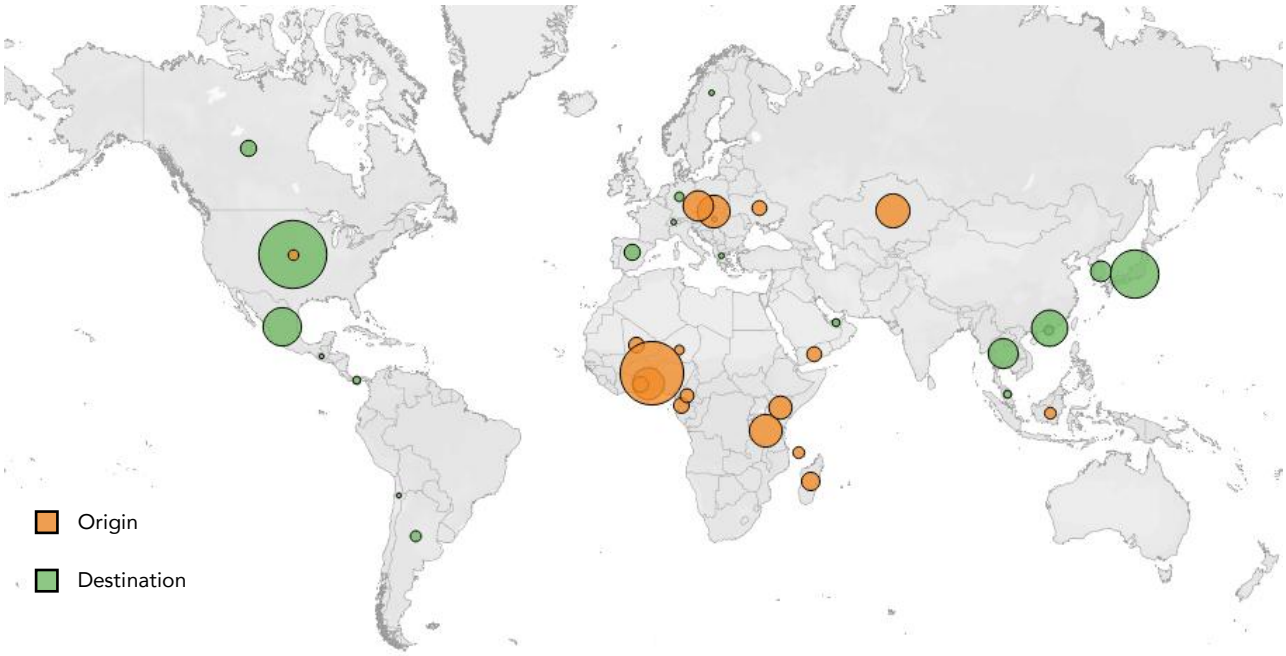


Figure 2d: A map depicting the top 20 origin and top 20 destination countries for re-traded chameleons, generated using Tableau software using CITES data 2000-2017. Size of circle represents the comparative volume of trade, largest origin countries are Benin (21,056) followed by Kazakhstan (6,046), Tanzania (5,969), Slovakia (5,801), Togo (5,375), Czech republic (4,771) and Kenya. Largest re-export countries are Ghana (22469) and the USA (19250). Largest destination countries are USA (24176), Japan (12775), Mexico (8112), Hong Kong (7203) and Thailand (4691).

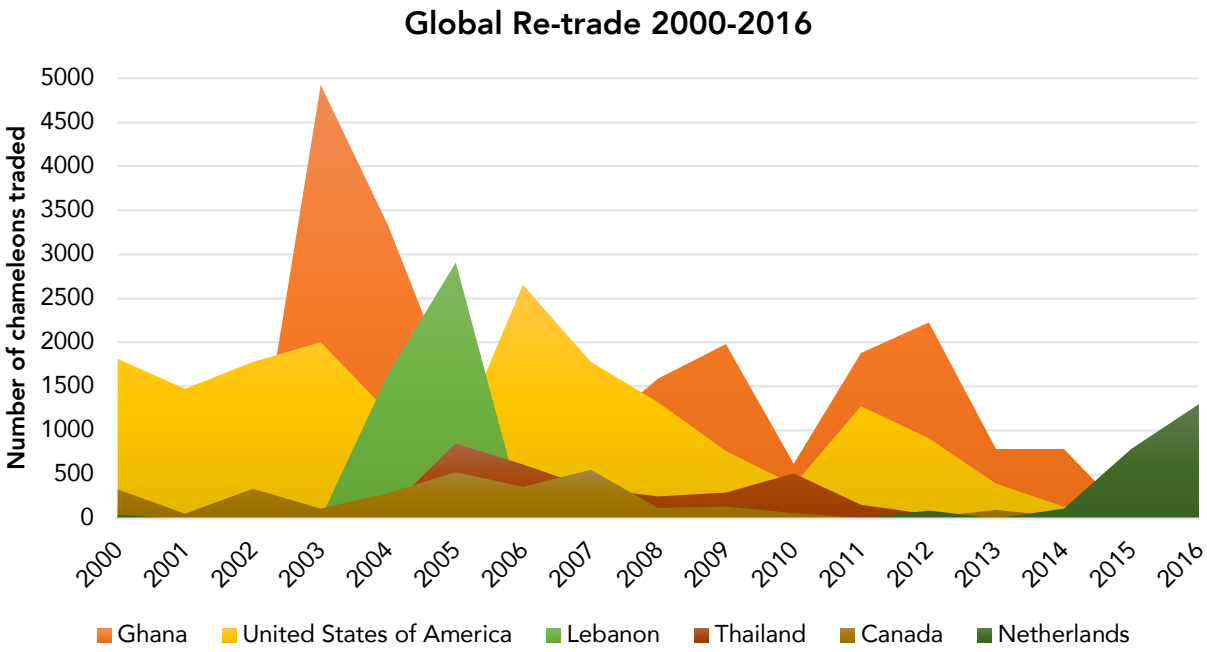


Figure 2e: Global re-trade of chameleons, as we can see the USA has played a consistent role over the study period with Ghana adding large volumes to the trade but in a more erratic pattern. The Netherlands has emerged in the last three years of study as a global hub.

Of the chameleons that are comprising the re-trade market over two thirds are from the genus *Chameleo*, higher than in the primary export market (figure 4a). The supremacy of *Chameleo* is partially explained by Ghanaian hub in West Africa where chameleon species are largely from the *Chameleo* genera.

Sourcing

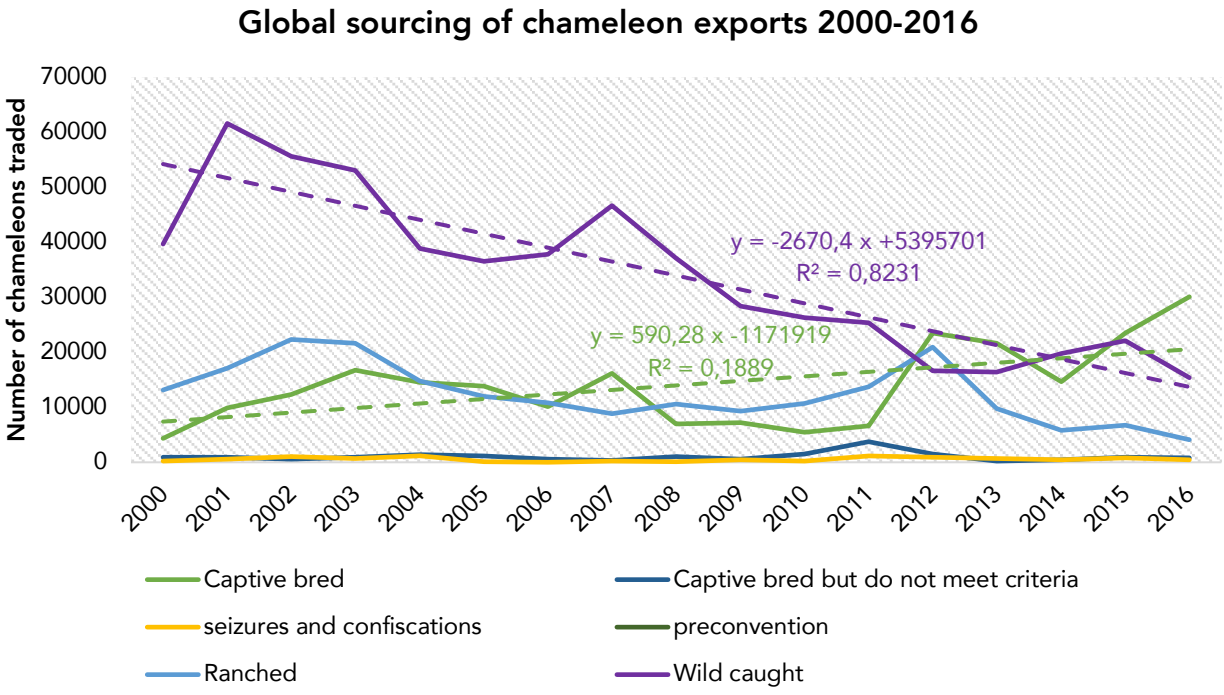


Figure 3a: Global sourcing of chameleons over the study period. Regression analysis for wild capture showed a very significant trend p=0,0000002, captive bred exports also exhibited a trend p=0,07.

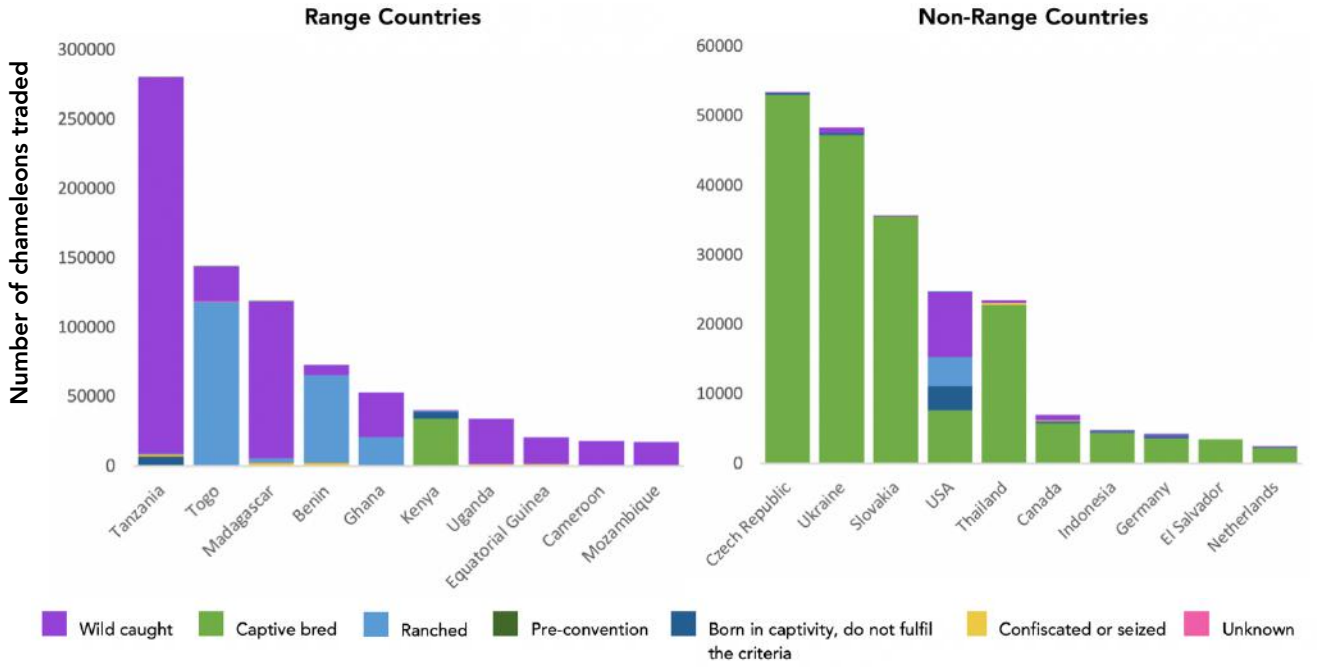


Figure 3b: Sources of chameleons exported by nations within and without the range of chameleon species.

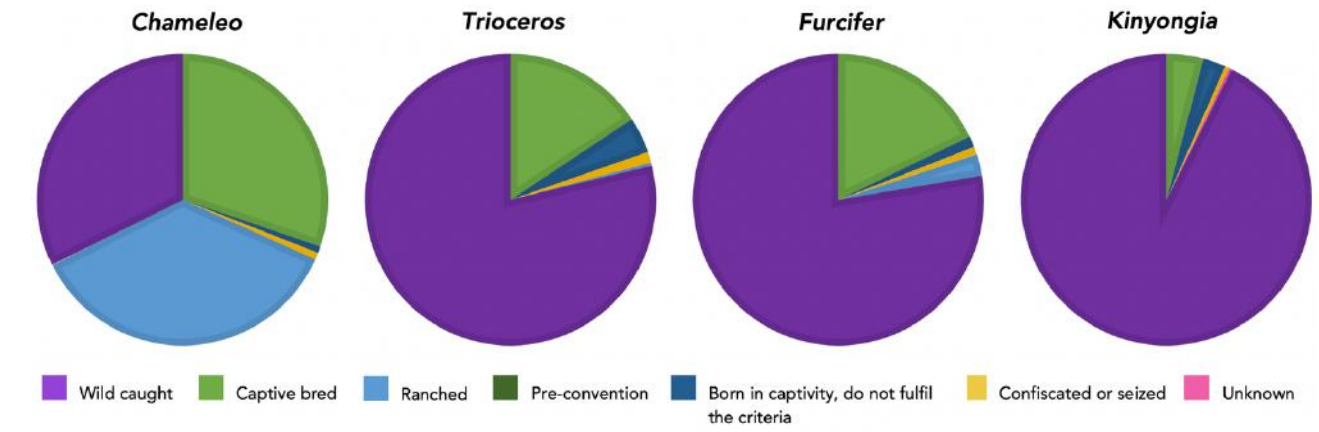


Figure 3c: Source of chameleons by genera, top 4 most exported genera in the CITES database.

Looking at the sources of chameleons for the global market we can see from figure 3a that globally a large portion of the chameleon trade was sourced from the wild however ranched and captive specimens contribute in an increasingly significant manner across the study period. Looking at a breakdown of this by origin (figure 3b) it is clear ranched and captive bred trade emanates almost exclusively from non-range countries whilst trade from range countries is dominated by wild caught specimens. It is also worth noting that of the top four most traded genera ranching and captive breeding only make up a majority in the *Chameleo* species whilst the other increasingly rarer genera are predominantly collected from the wild (figure 3c).

Diversity in trade

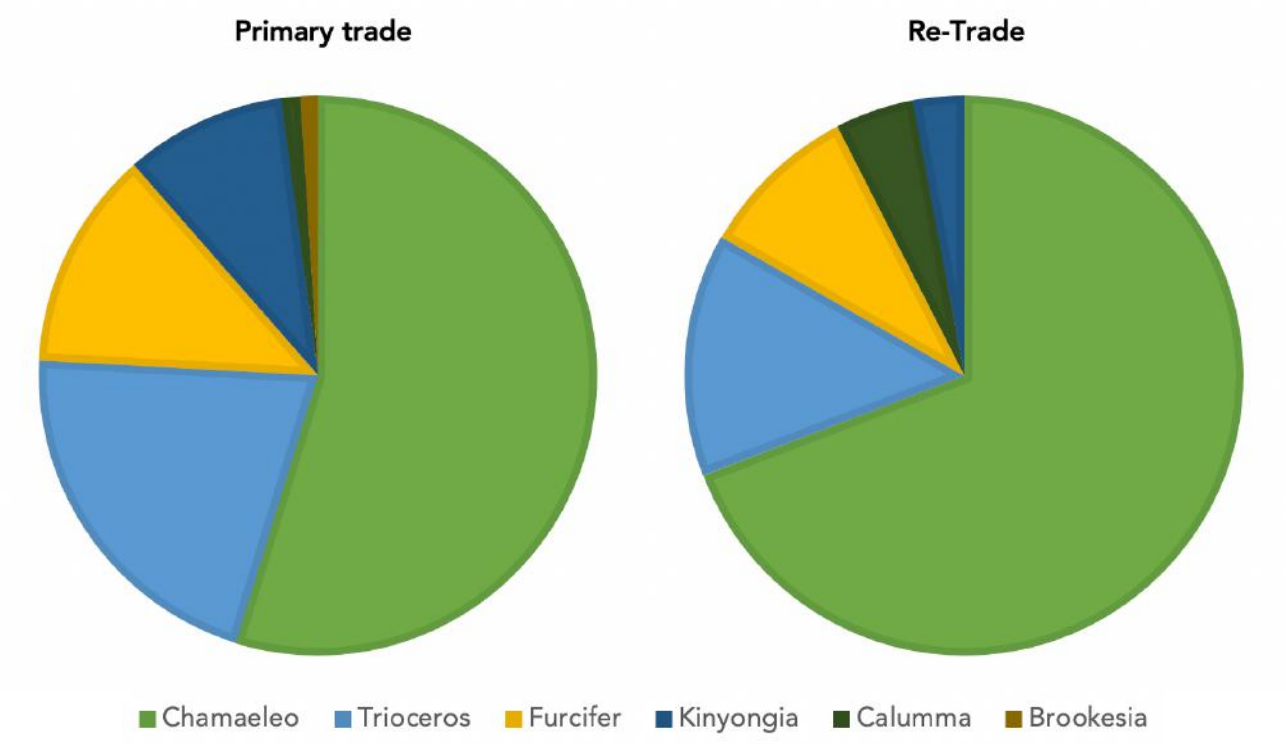


Figure 4a: The species composition of primary global trade and the trade from hubs globally.

Globally the primary and secondary exports of chameleons are made up predominantly of 4 genera, *Chameleo, Trioceros, Furcifer* and *Kinyongia*, with *Chameleo* being the most popular of these by a wide margin in both primary and secondary exports (figure 4a).

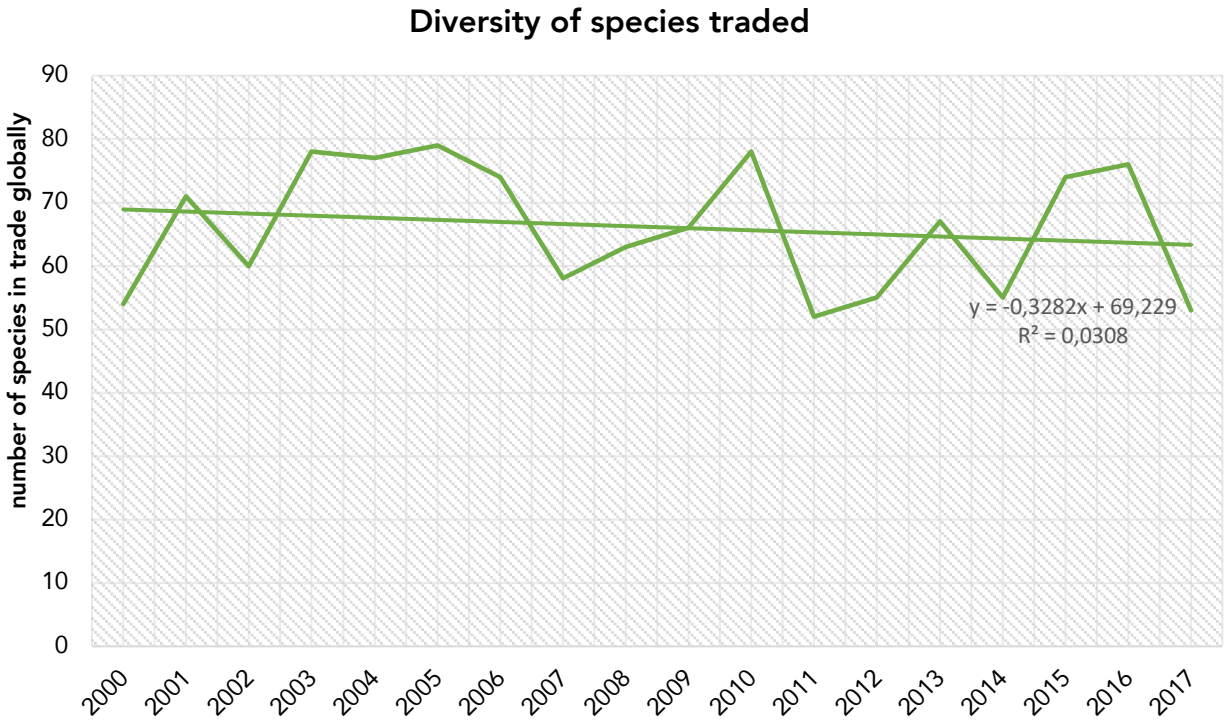
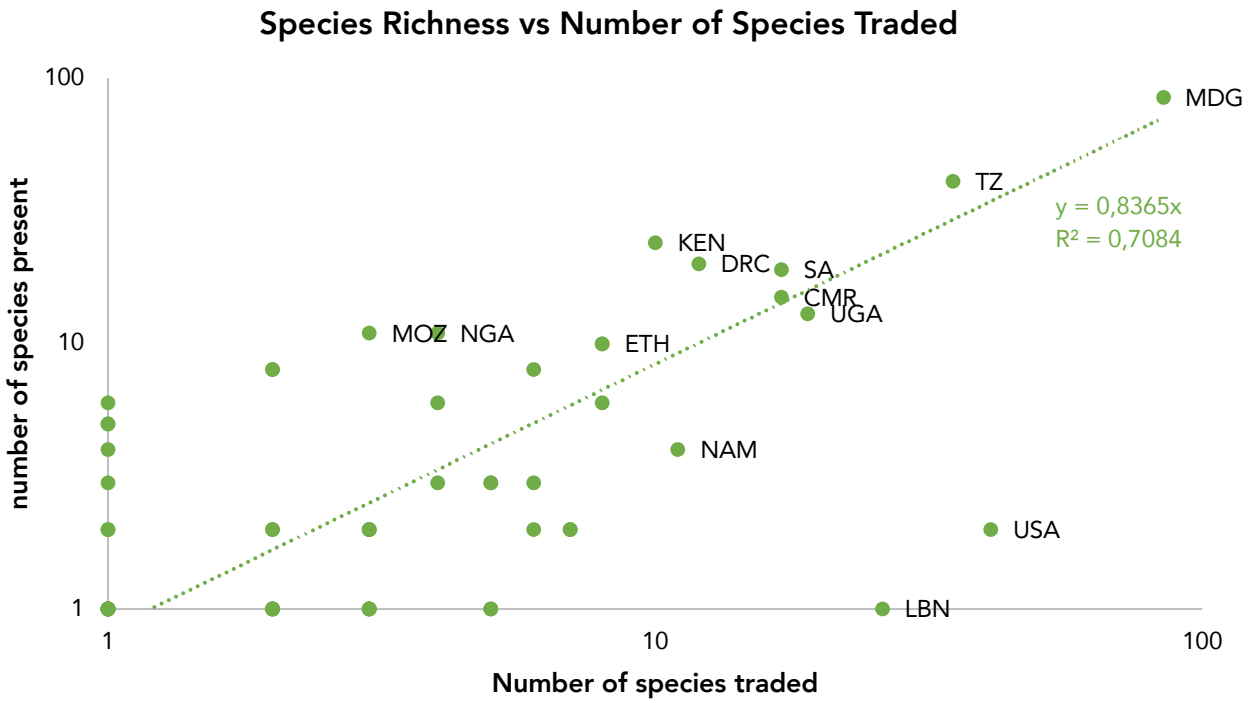
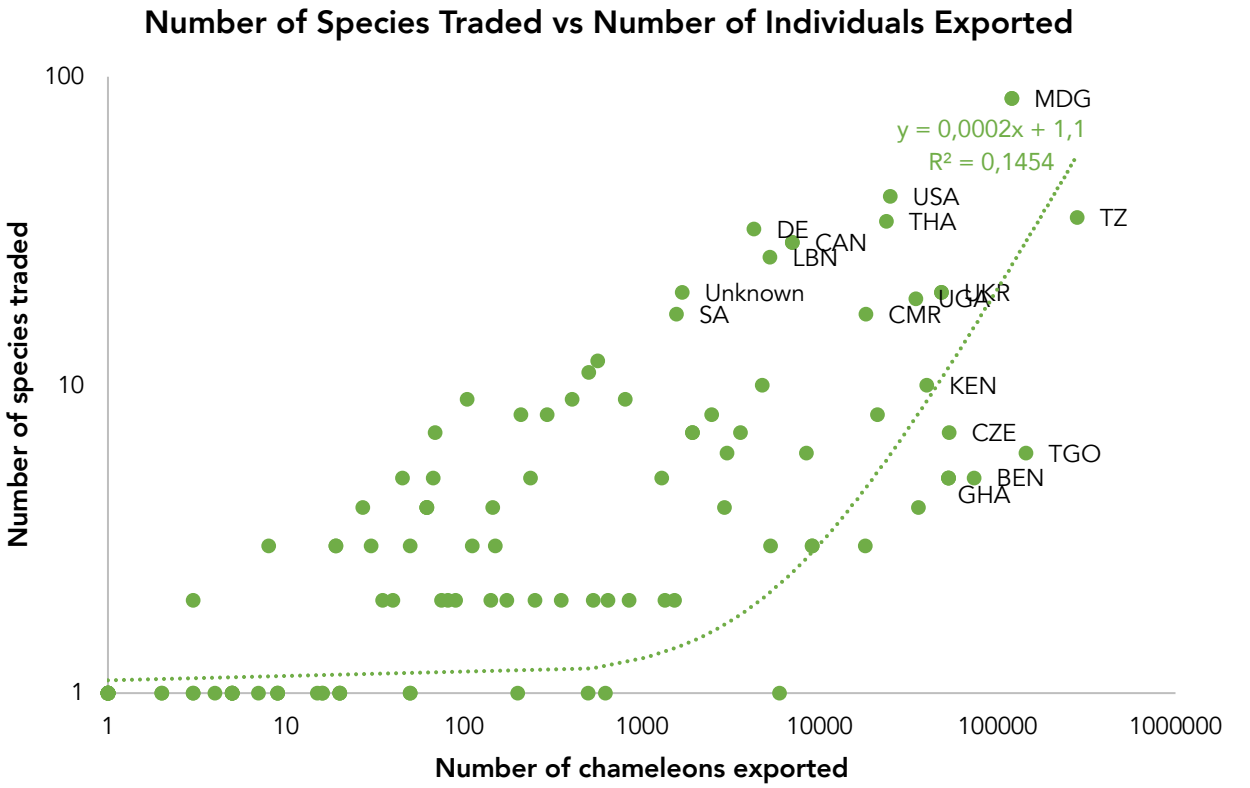


Figure 4b: The number of species traded globally over the study period, whilst it has fluctuated there is no clear trend p=0,486.





MDG: Madagascar, TZ: Tanzania, SA: South Africa, CMR: Cameroon, UGA: Uganda, DRC: Democratic Republic of Congo, KEN: Kenya, USA: United States of America, LBN: Lebanon, NAM: Namibia, ETH: Ethiopia, NGA: Nigeria, MOZ: Mozambique, DE: Germany, THA: Thailand, CAN: Canada, UKR: Ukraine, CZE: Czech Republic, TGO: Togo, BEN: Benin, GHA: Ghana

Figure 4c: The relationship between the number of chameleon species present in a country compared to the number of chameleon species that country exports (left) and the number of chameleons a country exports and the number of chameleon species exported (right). Logarithmic scale used.

Globally trade diversity has fluctuated over the study period but the is no clear trend for an increase or decrease in diversity of species traded. There is a strong positive relationship between the number of chameleon species present in a country and the number of chameleon species that country trades (figure 4c), put simply if a country has access to rarer chameleon species it will trade in them. Additionally the relationship between volume traded and diversity of trade is similar to the last review on chameleon trade (Carpenter et al, 2004).

Tanzania's role in global trade

As the largest exporter of chameleons analysis of Tanzania's role in global trade was important to understand drivers of trade and the impacts it can have not just in Tanzania but in other source countries. From analysis of the CITES database we can see that the largest single country destination for these animals was the USA however there were large markets in western Europe and East Asia (figure 5a).

Figure 5a: A map showing the destination of chameleon exports from Tanzania 2000-2017. Largest importer of Tanzanian chameleons is the USA, with a margin of 104,605 separating it from the next biggest, Germany. We can see clear markets in North America, Western Europe and East Asia.

Figure 5b: A map showing the destination of chameleon exports 2000-2017 from the USA, the largest re-exporter of Tanzanian chameleons. Largest importer from the US is Mexico 2239, followed by Hong Kong with 673 and japan with 608. We see the majority of re-exports are to North America and East Asia with very little going back across the Atlantic to Europe and Africa

Secondary trade in Tanzanian chameleons was almost entirely from the USA, 4919 compared to the next closest exporter Ukraine which only exported 283 chameleons. The destination of these chameleons re-exported from the US is shown in figure 5b

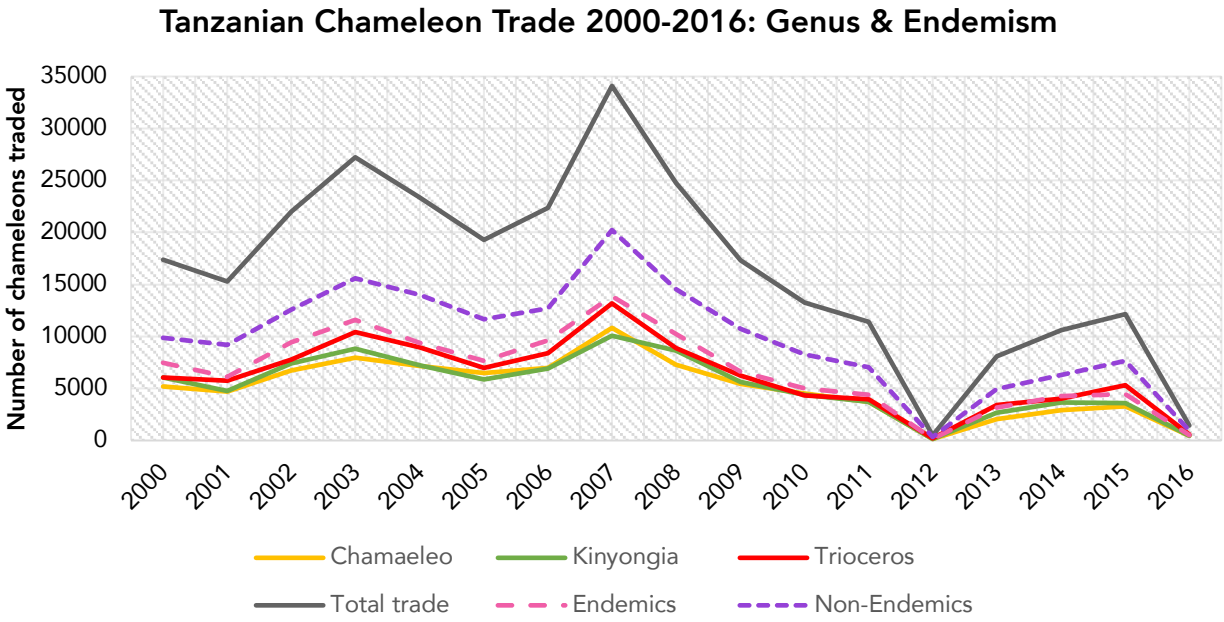


Figure 6a: Chameleon trade from Tanzania 2000-2016. Endemics comprise 40% of all trade in chameleons from Tanzania over the study period

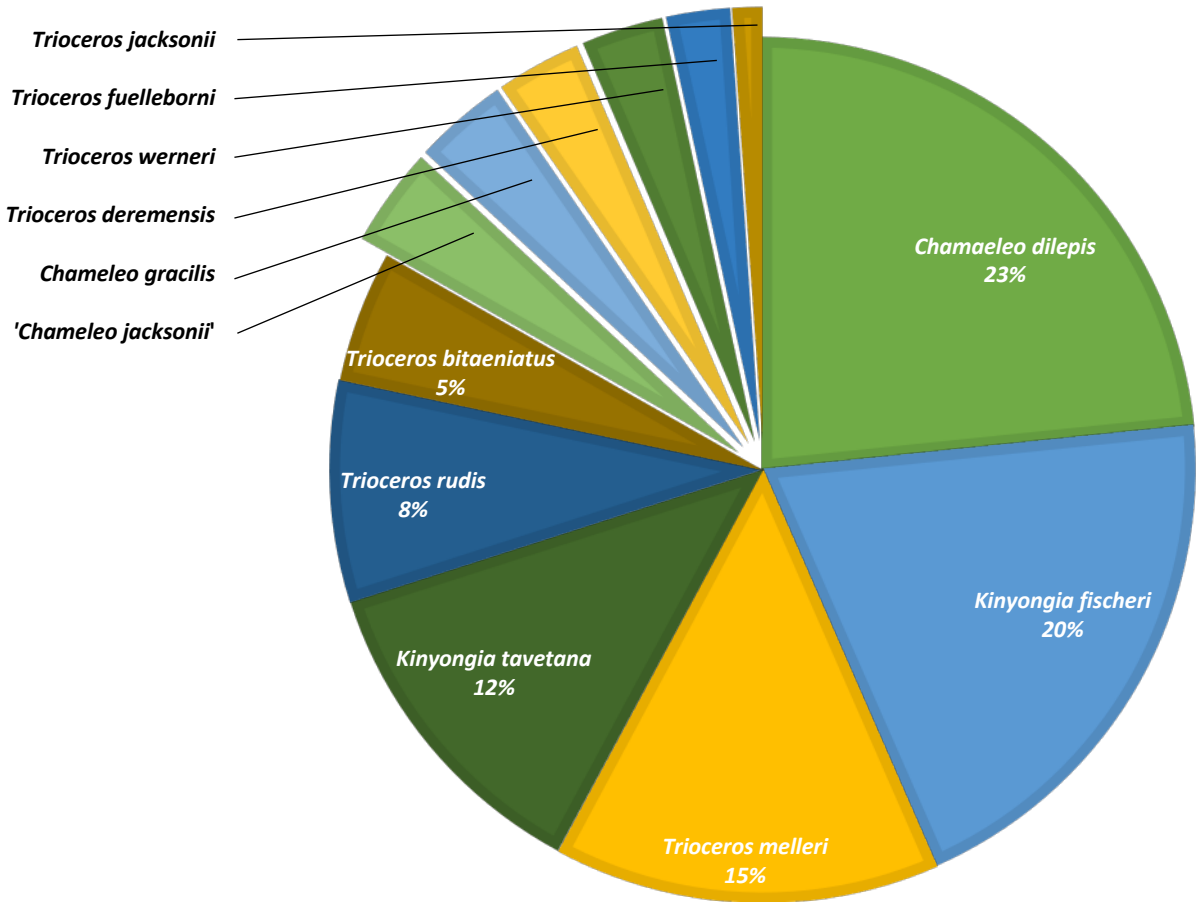


Figure 6b: a pie chart showing the top species making up primary chameleon trade from Tanzania

In contrast to global genus trends, trade from Tanzania is fairly even across *Trioceros, Kinyongia* and *Chameleo*, and actually *Trioceros* is consistently the most traded genera (figure 6a). We can see that across these three genera the same temporal pattern in exports is observed. The trend in endemic compared to non-endemic trade is also shown in figure 6a to highlight the importance of this sector in overall Tanzanian exports.

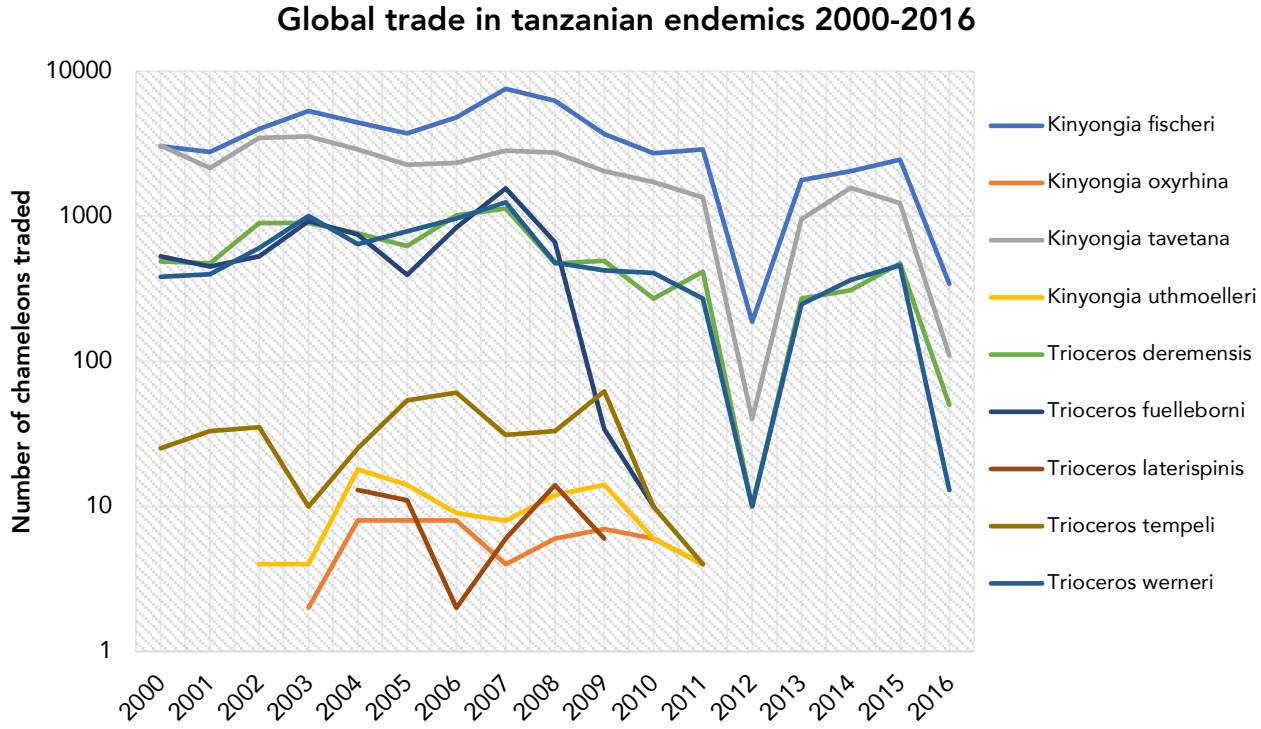


Figure 6c: Graph showing the global trade in chameleon species endemic to Tanzania 2000-2016 using CITES data. Logarithmic scale used.

Looking at this trade in endemics we can see there are some species that are significantly more popular than others, Species appear to cluster into three groups of the most commonly traded, those of medium popularity and those uncommonly traded. The most common cluster comprised *Kinyongia fischeri* and *K. tavetana*. The second cluster included *Trioceros werneri, T.deremensis* and *T.fuelleborni* (until 2008). The least traded cluster contained *T.tempeli, K.uthmoelleri, T.laterispinis* and *K.oxyrhina* (figure 6c). Records of trade in these species are almost entirely Tanzanian exports, implying there is little secondary trade in these species.

The trade from Tanzania is overwhelmingly commercial as is to be expected from such high quantities of animal trade. The global trend for nations within the natural range of chameleons to be exporting almost entirely wild caught specimens (seen in figure 3b) holds true for Tanzania to a very high degree with there being almost no ranched or captive bred specimens exported in the 20 year study period.

Online trade

The role of the internet in the global trade of chameleons was also investigated. All chameleon species present in Tanzania were assessed. Of the 42 species assessed for 83.3% of species there was evidence of online sale and 69% were actively for sale with prices listed. Price by species are shown in figure 7a. Prices were on average highest for *Triceros* species, followed by *Kinyongia*, *Rieppeleon*, *Rhampholeon*, and *Chameleo*. The market for endemics was also assessed (figures 7a & 7b) there was no clear relationship between price and endemism .

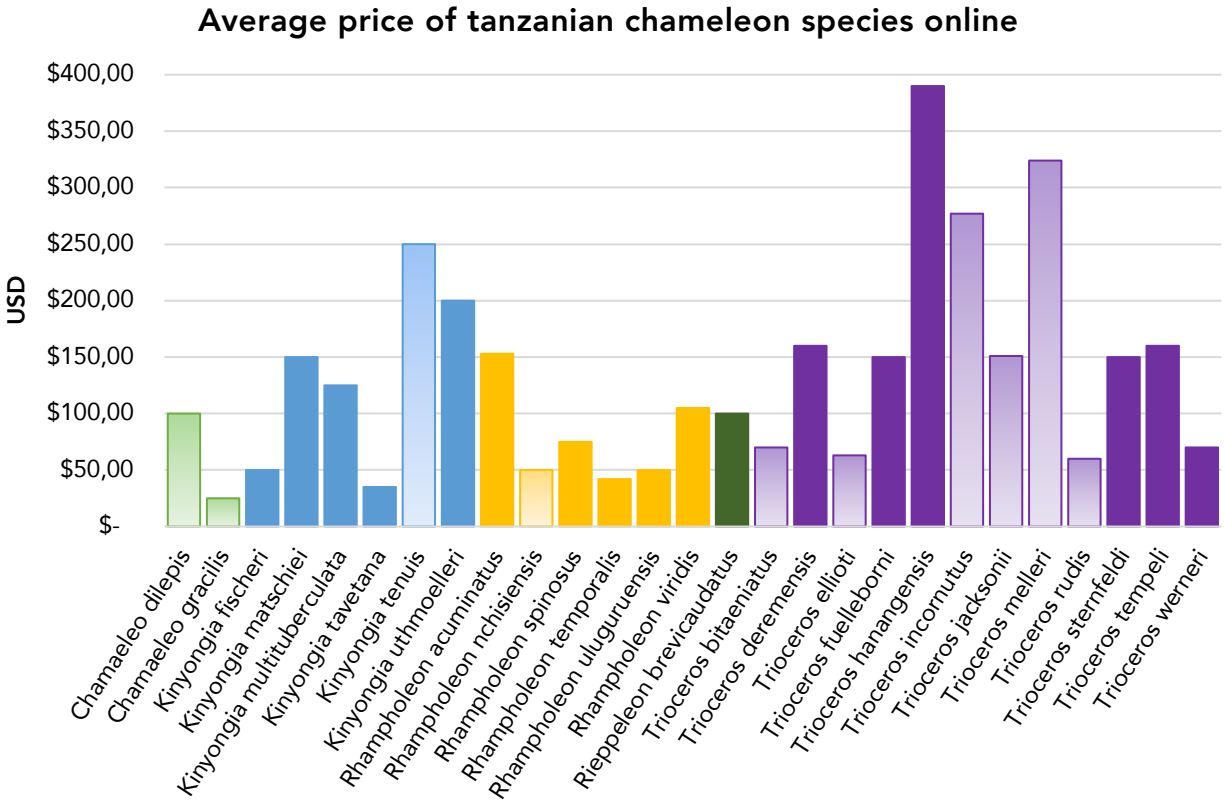


Figure 7a: A graph showing the average prices charged online for chameleon species found in Tanzania, Tanzanian endemics are in block colours, non-endemics are lightly shaded. Colours represent different genera

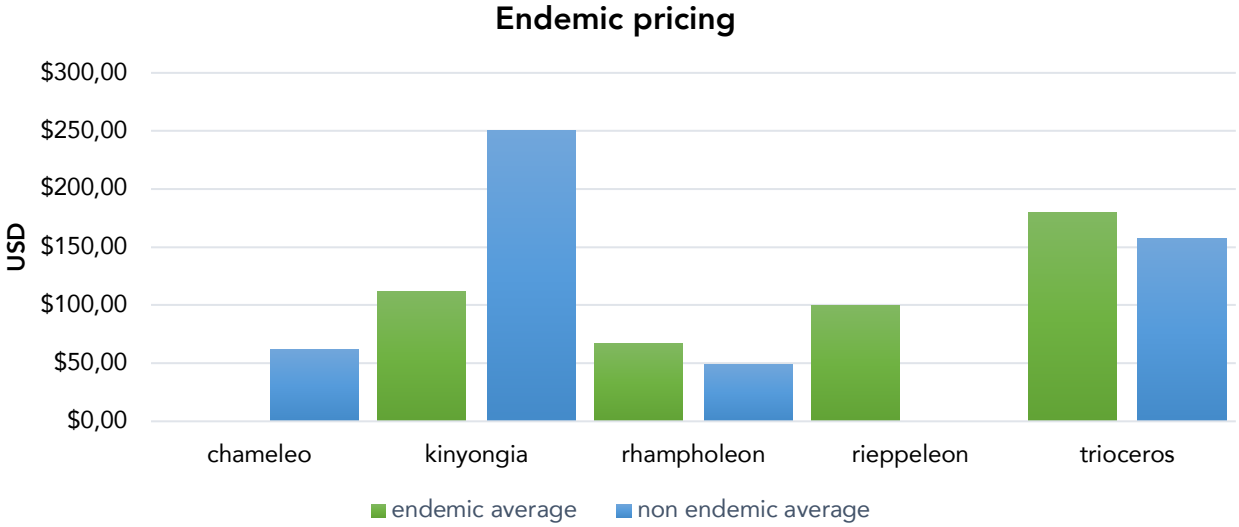


Figure 7b: A graph showing the average prices for endemic species of the chameleon genera present in Tanzania compared to the average price for those species that are not endemic

The intention was to enter hobbyist Facebook groups and see the impact of social media on this market, however despite joining 9 'groups' revolved around East African chameleons and surveying the pages for many chameleon suppliers and exotic pet stores there was little evidence that these species are sold through Facebook as there is a strong awareness of the community guidelines which forbid the sale of live animals and this appears to be enforced stringently by curators of these pages for fear of having their accounts suspended. Largely these pages just existed as signposts for websites and events outside of Facebook selling these animals. There was also little evidence of sale of animals on Instagram although there are many active accounts posting photographs of their captive East African chameleons. The impact on such content on demand for these animals was unable to be assessed within the scope of this report and would require a more technology driven approach to accurately assess (Minin et al, 2018).

One of the largest sources of specialist chameleon species online was online forums, the largest and most consistently updated being chameleonforums.com the forum itself is run by long time hobbyists many with developed knowledge of the CITES regulations and the conservation status of many chameleons. However there are many posts advertising shipments of endemic and hyperendemic species, often priced only in private messages to the account posting the ad. This lack of transparency make it hard to assess the volume and legality of trade in these species. Additionally, there is a widespread belief that most species are threatened by habitat loss not collection for the pet trade. Similar misinformation surrounds permits and quotas with there being significant misunderstanding of the CITES processes and separate country regulations.

Sourcing within Tanzania

Interview responses revealed only two of the mountain blocks surveyed were shown to be participating in the trade, the East Usambara and the Uluguru mountains. Of these two the Uluguru mountains had higher levels of reported harvesting, ~15000 chameleons cumulatively leaving the villages surveyed per annum compared to ~6000 in the Usambara. It is possible that many more are leaving the mountain ranges as a whole as this just covers the villages surveyed. However as similar numbers of villages were surveyed in each location this can be used to compare the intensity of harvesting effort across the two mountain blocks.

The Uluguru also had higher numbers of respondents able to comment on the intricacies of the trade, however the Usambara reported higher prices per chameleon (figure 8b) and less variability in numbers quoted (figure 8a). The Uluguru mountains are a highly transformed landscape with very little montane forest existing outside of the Uluguru forest reserve and substantial human populations even at high altitudes it is hypothesised that this would explain the greater harvesting as there is a larger labour base and as a result greater harvesting effort, it may also go some way to explaining the disparity in price, with more collectors comes greater competition and thus lower prices paid per chameleon.

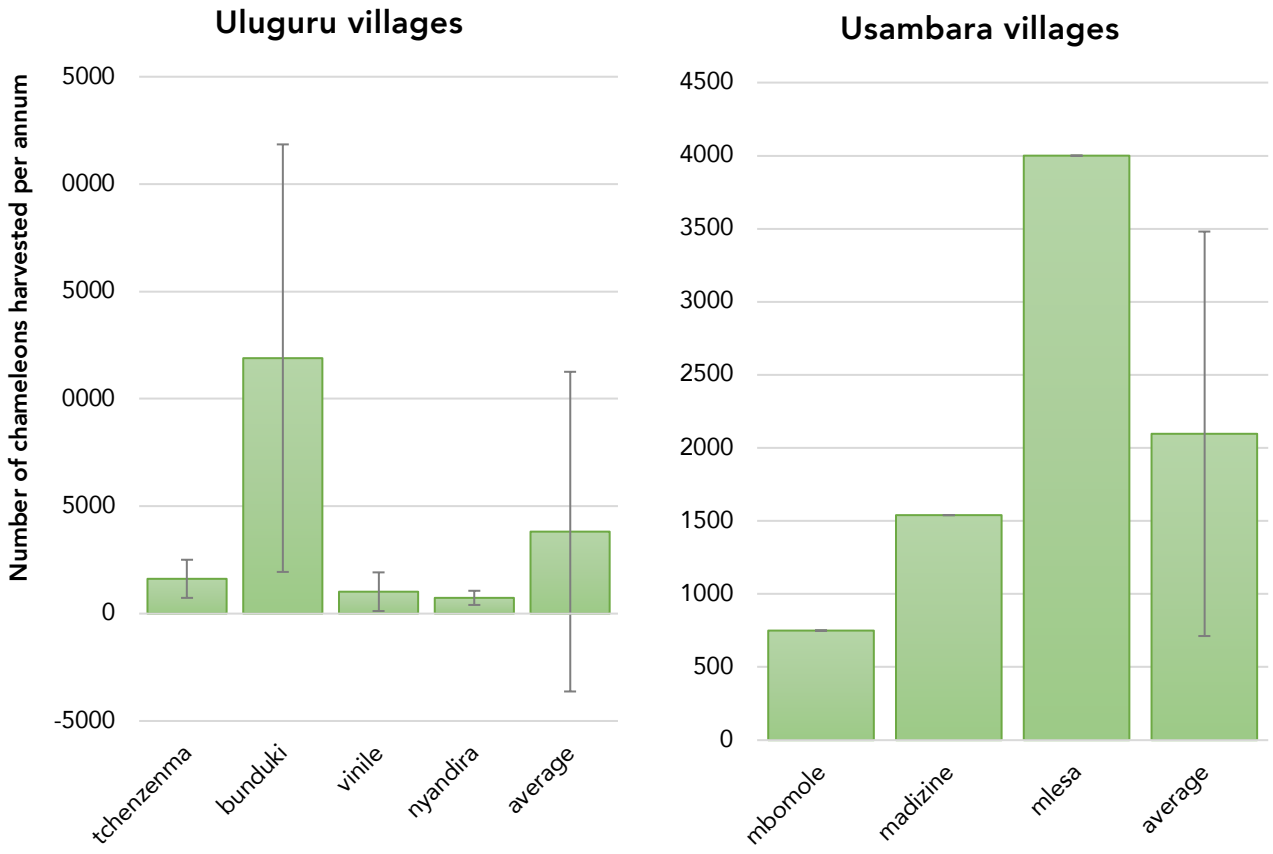


Figure 8a: Graphs showing the average yearly exports from each village sampled in the Uluguru (left) and Usambara (right). Standard deviation was high in the Uluguru but for the Usambara was not possible to plot due to the small number of interviewees able to estimate numbers with confidence.

In both mountain ranges the responses were in relation to trade in the past with respondents agreeing that trade was no longer happening, although estimates of how recent the trade was still functioning varied widely from a year to four or five years previously. There was consistency in the certainty that trade had stopped, whilst many local people were aware that the trade was now banned by the government this study finds it unlikely that every respondent was aware of this and was avoiding incriminating themselves.

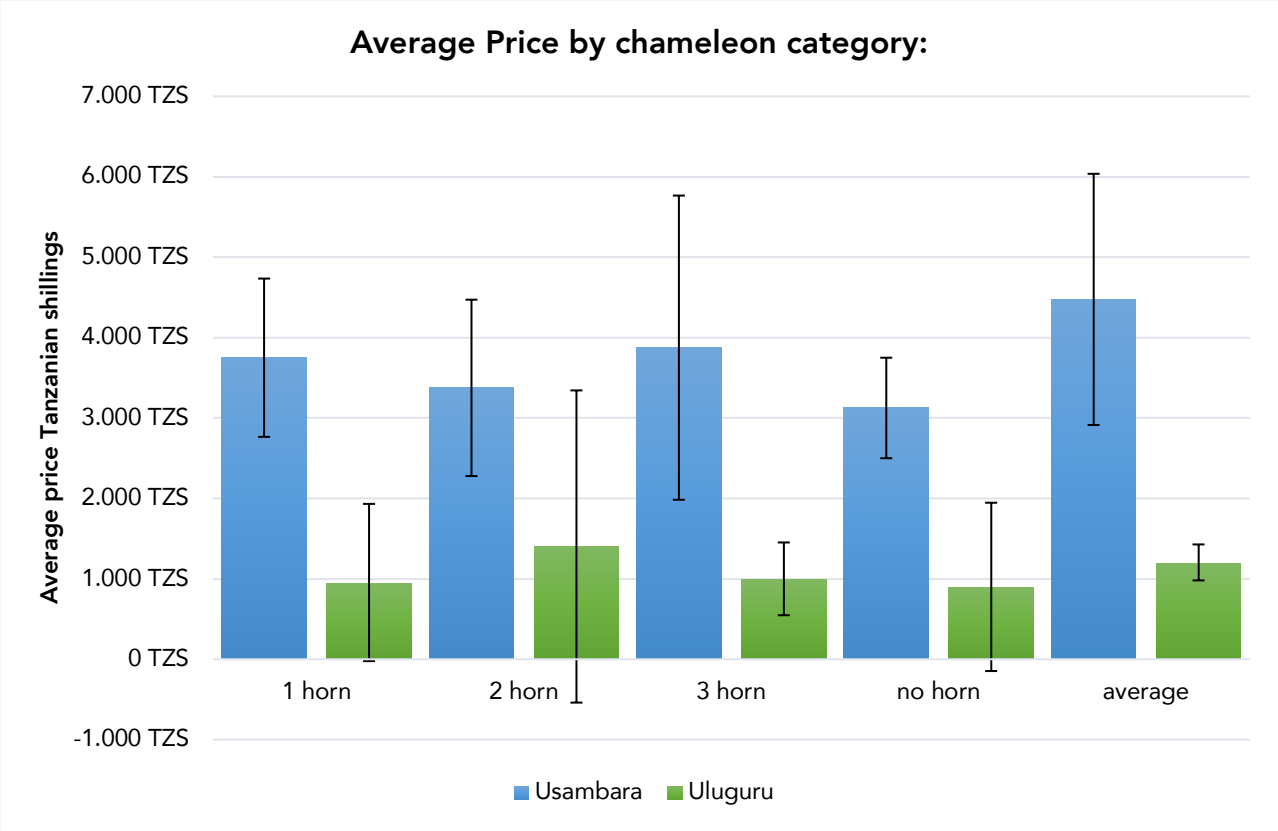


Figure 8b: Average prices paid to local collectors in Tanzanian shillings (1USD= 2299TZS [01/08/2019]) for different chameleon categories. In the Uluguru the two horned species commanded the highest prices, whilst in the Usambara it was three horned species. Across both mountain ranges the lowest value chameleons were those without horns. Prices were consistently much higher in the Usambara compared to the Uluguru mountains as shown by the average columns of 5,341tz compared with 1,205tz. Giant chameleons were excluded from this graph for clarity due to the fact that the prices quoted were very high and from limited sources, casting doubt on their reliability

Popularity of different types of chameleon was also investigated (figure 8c). Species specific popularity can only be inferred from the data as local people were not familiar with species identification and thus classified species by physical characteristics, namely how many horns they have, one, two, three or none or by body size, namely the giant chameleon *Trioceros melleri*. This type of classification means that due to sexual dimorphism and females having different numbers of horns to the males, or none at all this makes species specific commentary hard to achieve, however there are only some species in each area which fulfil these criteria, detailed in figure 8d. In some cases the classification by horn number narrows it down to only one possible species (*K. oxyrhina* and *K. uluguruensis* in the Uluguru, *T. deremensis* & *K. matschiei* in the Usambara) however in some cases there are several possible candidates, this is particularly true for specimens with no horn. However what is

clear from interviews is that horns were a sought after characteristic by agents, this was also reflected in prices quoted for different types, with horned chameleons being priced higher than those with no horns (figure 8b). Additionally three horned species were exported in higher numbers over the study period compared to one horned species despite the local value not being much different for these categories (figures 8c and 8b respectively).

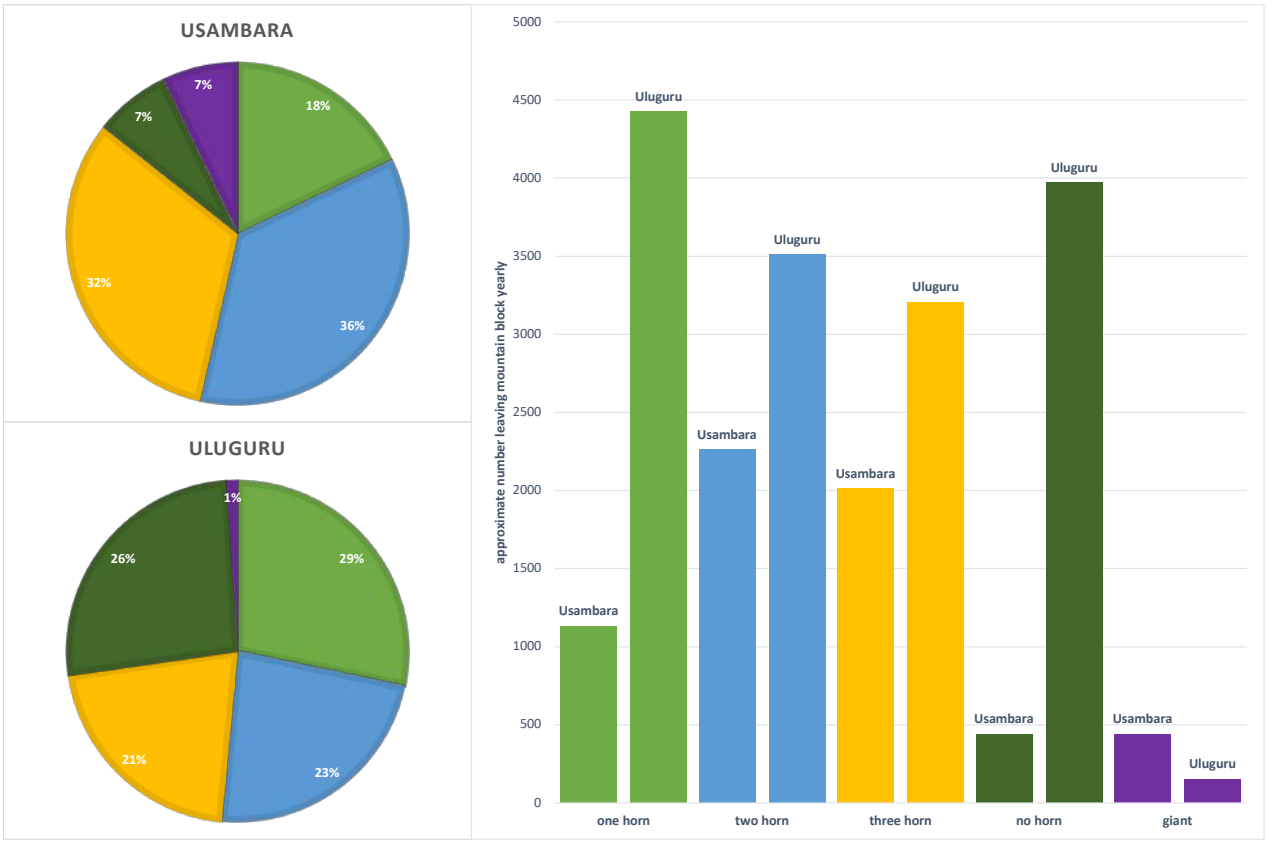
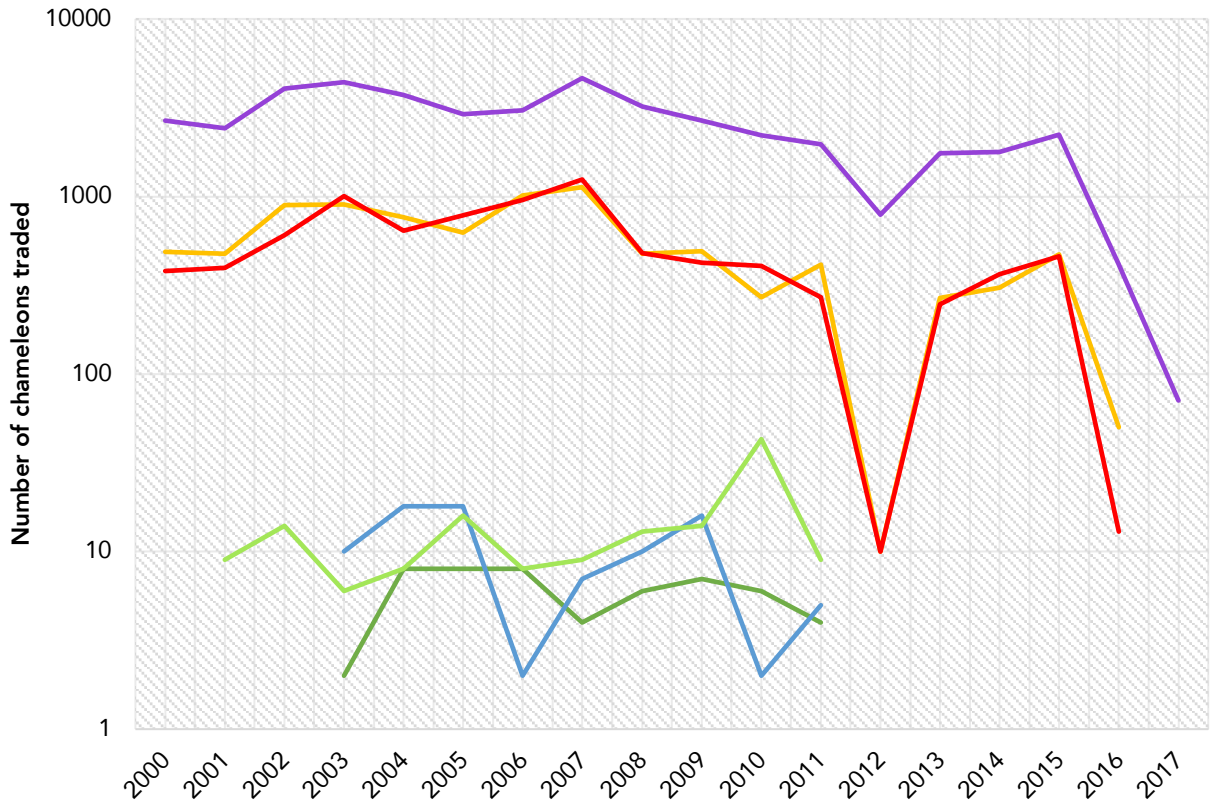


Figure 8c: Pie charts showing the showing the percentage of interviewees that mentioned each category of chameleon as being sought by collectors in the Usambara and Uluguru mountains and how this is divided across the numbers quoted by interviewees

Interestingly despite the large numbers quoted as leaving these mountain ranges when we crossreference these reports to the CITES trade database they do not match up very well all as we can see in figure 8d, with no two horned species present in either mountain range being recorded as leaving Tanzania in the whole study period and all of the one horned species (*K. oxyrhina* & *K.tenius*) being practically negligible trade despite local reports of thousands leaving yearly (figure 8c)



	One horn	Two horn	Three horn	No horn	Giant
Uluguru	*K. oxyrhina*	*k. uluguruensis*	*T. deremensis*	*Rieppeleon brachyurus*	*T. melleri*
			T. werneri	All *Chameleo* species	
				females of species	
Usambara	*K. vosseleri*	*K. matschiei*	*T. deremensis*	"	*T. melleri*
	K. tenuis				
	Rhampheleon spinosus				

Figure 8d: A table showing the species of chameleons that could be those mentioned by villagers surveyed in the Usambara and Uluguru mountains, those present in the CITES trade database are highlighted in the colour they correspond to in the attached graph.

Qualitative and anecdotal results

Interviews showed local sentiment towards conservation and the inherent value of nature in these mountain blocks may also have significant influences on the number, honesty and type of responses given; for example the respondents in the Usambara were more hesitant to admit knowledge of the trade and reluctant to say selling these animals for profit was a good thing and expressing reservations about losing chameleons from the area; by contrast it appears that the residents of the Uluguru mountains have lost touch with the forest due to the landscape being highly transformed, and whilst more forthcoming in interviews did not mention these factors.

Another factor impacting the responses given in each mountain may be the longer conservation presence in the East Usambara with the establishment of Amani nature reserve predating the Uluguru nature reserve by thirteen years (1997 vs 2009). This maybe be genuinely having an impact on local views on conservation and improving attitudes towards nature but equally it may have taught local people to operate in much more secrecy when conducting wildlife trade. It was infeasible within the scope of this report to establish the effect of this factor

Across both mountain blocks awareness of why these chameleons were in demand was low, with the majority of respondents saying they didn't know and/or that they didn't care what the chameleons were used for after leaving the mountains, this reflected a view of wildlife products like these as being a source of income and not much more than that. In the Uluguru people were more aware of potential uses with many suggesting they were 'ornamental' and for 'tourism' with some suggestions being their use in snake parks and other attractions, considering there have been no zoo/research exports in the CITES database this may explain some responses mentioning zoos and researchers sourcing from the mountains, a story also heard in the Usambara. Additionally only one respondent mentioned the possibility they could be used for medicine and this lack of medicinal claims was corroborated by Mourice Mbunde a specialist in traditional medicine at Muhimbili University in Dar es Salaam; he said that in his years of research he had never seen or heard of chameleons being used in traditional medicine in Tanzania and found it unlikely to be an unknown market due to chameleons not being well liked in Tanzania and generally being seen as a bad omen

Reliability of surveying

The reliability of the responses in the two mountain blocks is comparable however there are significant differences in the response quantity and quality over the two mountain blocks. In the Usambara there were fewer people able to comment on the trade compared to the Uluguru however reliability of the accounts received in the Usambara was higher due to many of the interviewees being people directly part of the collection and with first hand knowledge of selling chameleons; therefore their answers are comparable to the significantly larger number of responses that are in agreement in the Uluguru.

Other factors that are important to be taken into account are the distribution of the villages surveyed. The villages in the Uluguru mountains are more distant from each other so give a better picture of harvesting effort surrounding the reserve, with there being a lower likelihood of repeats in the harvest data, whilst in the Usambara villages were walking distance from each other in some cases and respondents reported agents stopping first at one village and then walking up to another

Udzungwa mountains

This study found scant evidence for a significant chameleon trade from the Udzungwa mountains and the Magombera forest with only one respondent across both locations reporting being paid for finding chameleons. There are many possible reasons for this,

firstly the Udzungwa mountain block is covered almost entirely by national parks and reserves, additionally the region closest to major roads is a national park which has a higher level of protection than forest reserves and trespassing/collecting carries a high risk of being arrested or shot by armed park rangers. As such it appears that either collectors must risk these punishments to collect in the national park; or must travel 5 hours or more, further south along the mountain range to source from the Kilombero nature reserve. From the interviews and follow up questions it seems that the national park regulations are well known of and strictly followed and the extra distance to Kilombero seemingly proves to be unprofitable as villages surveyed around Kilombero nature reserve also had no record of chameleon trade.

It may also be the case that even to get to the closest part of the Udzungwa mountain range is 8+ hours by road from Dar es Salaam, seemingly the exit point for these animals from the mainland, and as such the profitability of transporting live animals long distances by road is small compared to close mountain blocks such as the Uluguru and Usambara mountains.

Another factor that may affect the presence of wildlife trade is the absence of people from the mountain range, the area has been a national park since 1992 and before this the area was a forest reserve so has been uninhabited for a long time, this means that the closest villages to the mountains, those surveyed, are at the base of them on the edge of the Kilombero valley. Throughout the interviews it was clear that people's livelihoods largely revolve around the agriculture of the Kilombero valley rather than the mountains, a very different relationship to those communities surveyed in the Uluguru and Udzungwa.

Interestingly there was evidence of wildlife trade in other taxa such as snakes and tortoises in the Udzungwa suggesting a value threshold that animal products must clear to overcome the risks and costs of sourcing in this area however these species were not mountain specialists and could be sourced both inside and outside protected areas. Some people reported Europeans and Africans acting as agents for Europeans coming from the Selous game reserve trying to source these animals, and so it may just be opportunistic with the bulk of the sourcing of these animals occurring elsewhere. The appearance of poachers from Selous also nicely demonstrates the difference in protection level between a national park (Udzungwa) and a game reserve (Selous) and the effect that different management bodies can have on protection of wildlife

From mountains to exit points

Previous research had identified that Usambara chameleons pass through a succession of middlemen however the drivers and path have not been accurately identified (Patrick et al, 2011). From the local interviews in the Uluguru and Usambara mountains it was clear a fairly ordered system exists connecting these remote mountains to the international market. Villagers in both mountain blocks mentioned agents coming from larger settlements at the base of the mountains (Muheza in the Usambara and Morogoro in the Uluguru) with an order for a certain quantity of chameleons with types specified (one horn, two horn, three

horn, giant etc), they would then give a time frame, usually a couple of days before returning to collect them or having them sent down the mountain with a courier, from there they would be transported to Dar es Salaam (although there was one account in the Usambara of them historically being sent to Mombasa in neighboring Kenya). This was the broad structure given by interviewees and although small differences existed such as greater or lesser amounts of known middlemen the pattern of organized and specific orders was the same across the board and opportunistic collecting was unheard of.

In the Usamabara this study was able to contact and interview a middleman operating between the mountain villages and the larger town of Muheza at the base of the mountain, an informal interview was conducted giving an insight into the chain of trade emanating from these mountains. He suggested that the speed of sourcing chameleons was more important than the number collected which was usually just as much as possible, suggesting that the market is top down controlled by demand, that permits are an afterthought and that these animals are wanted alive. He also mentioned targeting specific villages based on the chameleons needed from the order, with different altitudes and habitats yielding different species. His role as an intermediary was passed down to him from his father and he suggested a history of this trade in the region. As with most other people collecting in the region he had no interest in what the chameleons were needed for and was motivated by the income provided by them. His commentary on the value chain was speculative with him making only marginally more ~1000tz than those collecting them for him in the villages and his perception being he receives 30% of the value of the chameleons with those in Dar es Salaam making 70% more per chameleon. His commentary on the legality of the collection was perhaps the most telling, he was told by the agent in Muheza that they had permits for collection, however he was never shown these permits, additionally he was told to collect more than the permits allowed, "it is some kind of game".

This project tried to establish the steps that may exist between these agents in Muheza and Morogoro and the final CITES export record for an individual chameleon leaving Tanzania, however in the time frame allowed could not establish contact with these agents and could not obtain exporter records from the ministry of natural resources in Tanzania. As such there is a knowledge gap on whether the chameleons harvested in these locations are exported legally, with papers and according to permit allowances, or whether they are leaving the country illegally and entering a black market.

When representatives from the Tanzania ports authority were contacted they insisted that large numbers of chameleons could not be leaving Tanzania through the airport or sea port in Dar es Salaam or through Mwanza on Lake Victoria, however due to different management authorities on Zanzibar they could not comment on Zanzibar being an exit point for live animals. Additionally experts in wildlife trade in Tanzania including Peter Sumbi (formerly of TFCG) suggested that land borders with Kenya are very easy to cross for Tanzanian people and had first-hand knowledge of this occurring for rare timbers. Unfortunately within the scope of this project it was not possible to confirm any of these statements.

Discussion

The aim of this thesis was to map out the current global trade in chameleons and the scale and nature of the threat posed to them globally by trade. As an under-researched family with high levels of endemism this study was essential in establishing the current picture of chameleon conservation globally by bringing up to date our understanding one of the primary threats to chameleons, global trade.

A multifaceted approach was used to understand the global trade in chameleons and assess the impact on their survival in the wild. This comprised an analysis of the CITES international trade database, an investigation of online trade in live chameleons and on-the-ground survey work in a source country surveying local people and conservation professionals. Because of the great diversity and wide range of chameleons this research involved focusing on a source country to illuminate fine details, Tanzania was chosen as it has never had its chameleon trade assessed in detail despite having the second highest diversity of chameleons globally, many of which are endemic species.

This report found that in Tanzania, the largest exporting nation of chameleons across the study period, 40% of the trade in chameleons recorded in the CITES trade database was in endemic species, additional to this there appeared to be very large discrepancies in the CITES database when compared to both online sales of chameleons and in country surveying of source communities. These discrepancies point to significantly larger volumes of trade in threatened species and markedly different species composition of exports than that which is recorded by CITES. Furthermore it was found that in the *Chamaeleonidae* charismatic traits, viewed as desirable by buyers, coincide with characteristics exhibited by endemic species and as such places them at greater risk. These parallel issues have large implications both for the conservation of endemic chameleons and usage of the CITES database for cryptic taxa such as the *Chamaeleonidae*. Possible explanations include a large black market trade in these species, misidentification of species entered into the CITES database, and high levels of mortality during transit stages.

Black market trade has been identified as a close bedfellow of trade in endemic flora and fauna and it has been established that endemics are desirable on the international reptile market and this persistent desirability could be an issue that drives black market trade (Auliya, 2003). This report identified the preference for horned specimens which provides insight into market demand, if this is indeed a black market and could suggest two things; the first possibility is they are used medicinally. Several academics contacted raised the suggestion that the horns from these animals could be valuable in East Asian traditional medicine. However there is currently no published material substantiating this and this study brought nothing to light that could corroborate these claims. There have been published examples of chameleons being used in medicine abroad; a study in 2017 found a high turnover of chameleons in Morocco both live and dead for medicinal purposes (Nijman & Bergin, 2017) which echoed a study from 1999 of the Nigerian market (Sodeinde

& Soewu, 1999). However in both of these cases it was made up of generalist *Chameleo* species (*C. chameleo* & *C. senegalensis*) so the possibility of a black market for chameleons, in medicine exists however the evidence of one, particularly mountain specialists is not provided by this report. The second explanation for the desirability of horned specimens, and indeed the prevailing assumption in global chameleon trade, is that they are being used for the pet trade and that the horns are a characteristic viewed as charismatic by collectors and thus desirable in the pet trade where exaggerated physical traits are appealing (Auliya, 2003; Collis & Fenili, 2011). The likelihood of an extensive black market for these endemic species appears low, this opinion is based upon the surveying of local collectors of chameleons for this research; they were commenting on the trade before stricter government regulation entered into force, with there being no evidence of this continuing after the introduction of this legislation. This presupposes that at least on some level the trade was going through official channels. If trade had always been on a black market one would expect very little disruption to the market operation.

It seems more likely to this report that exports from these mountain ranges are being incorrectly entered into the CITES database as other species. The source of this error is where there is a large grey area, it could be due to poorly trained customs officials and incorrectly filled paperwork or a deliberate mislabelling of species to circumnavigate quotas (Alfino & Roberts, 2019). With high levels of corruption permeating Tanzanian government (Kideghesho, 2016) it is not an impossibility that bribes are being paid to keep the existence of this trade under the radar. From the accounts given by local people and the middleman in the Usambara it seems as though collectors, middlemen, and exporters are exploiting the cryptic nature of chameleons and the authorities inability to distinguish between them to avoid following the strict guidelines stipulated by permits and quotas. Indeed in the words of one middleman "it is some kind of game". The existence of this 'grey market' in chameleons is seemingly the best fit for the discrepancies between the CITES database and online and sourcing reports. A grey market would be significantly more damaging to rarer specialists than generalist species and raises the possibility that many more range restricted species are being traded than is currently evident from the CITES database. If this grey market exists in Tanzania it could be indicative of a widespread problem facing endemic and cryptic species in developing nations globally which cannot necessarily allocate the large resources needed to train border staff and those issuing permits to such a high degree (Challender et al, 2015). As the data in the trade database is a significant part of what CITES uses in the justification of species evaluations, upon which quotas are based, these issues with cryptic species such as chameleons could have significant real world conservation impacts (Alfino & Roberts, 2019).

The third, more unlikely, possibility is that very large numbers are dying in transit between the harvesting and export stage. From interviewing collectors it was clear the conditions that the animals are sent down the mountains in do not appear favourable to a high survival rate, with hundreds of individuals of varying species being packed into cardboard boxes and strapped to the back of motorcycles for a long trip on dirt roads followed by a long trip to Dar es Salaam in the equatorial heat that highland species are not acclimatised to.

Indeed many hobbyists online talk of the 'battle scars' they often observe on chameleons imported from East Africa. In Tanzanian birds pre export mortality was estimated at 45-62%, (Howell, 1996) and reptile mortality pre-export is thought to be high as well (Flecks et al, 2012). Tough transport conditions such as this favour the survival of generalist species more than highly specialised endemic species, highlighting a hidden cost for highly specialised species and their heightened vulnerability in the global wildlife trade. This has knock on effect in more chameleons needing to be harvested for enough to make it successfully to their final sale point in a marketable position. It is this reports conclusion that while many chameleons must be dying in transit it is unlikely that the disparity between the interview data and CITES is caused by this factor alone. It also demonstrates a shortcoming in CITES policy to protect endemic and range restricted species by not factoring into conservation decisions the numbers behind each successful live export and how this can more profoundly effect range restricted species with small populations.

Another significant finding of this study was the emergence of Tanzania as a major world exporter of chameleons over the last twenty years. This pattern follows on from the last review of global chameleon trade that covered the period 1977-2001 and which identified Togo and Madagascar as the major global exporters of chameleons over that period with Tanzania in a more minor role (Carpenter et al, 2004). Tanzania continued to dominate global trade in chameleons until 2011and even after this remained a major player until 2016. Carpenter and others suggested that Tanzania emerged as major exporter of East African chameleons filling the vacuum left by the exit of Kenya from the trade in 1982. This research provides evidence of the same pattern of Tanzania filling the gap in the market left by Madagascar as trade declined over the course of the study period. Considering the dramatic increase in Tanzania's chameleon trade, the dominance of wild sourcing these animals and particularly bearing in mind the high level of endemic threatened species (Meng et al, 2016) the comparative lack of CITES attention is worrying. Species reviews were in years 1999, 2001, 2005, and 2017 and only included 6 species out of the 41 present in Tanzania, 2 of which are still subject to review. Considering the cryptic nature of these species and lack of extra resources required by Tanzania to train authorities to identify cryptic species it seems CITES' is falling short of its responsibilities. This corroborates previous criticism of the responsiveness of CITES and its inability to "consider the complex nature of demand or contend with changing market dynamics." (Challender et al, 2015). Looking past CITES it is interesting that a country such as Tanzania is so under researched despite having rich biological resources coupled with a poor track record on wildlife trade and a significant role in the global live animal trade (Kideghosho, 2016). Considering the underrepresentation of endemics in trade regulations globally and within Tanzania combined with the market demand for endemic reptiles (Janssen & Indenbaum, 2019) Tanzania should merit further research and regulation of its trade.

Whilst this study showed global trade in chameleons has decreased slightly over the study period this was predominantly in the genus *Chameleo,* and trade in other genera has remained constant. This pattern of dominant genera obscuring trade patterns for other genera has been seen in reptiles in the past (Robinson et al, 2015) and raises the suggestion

that there is detail missing in the global picture of reptile trade and that broad findings based on CITES data risks endemics falling through the gaps.

This study also found that wild capture is decreasing and captive breeding increasing in the reptile trade, a recurring trend observed in literature (Harfoot et al, 2018). However here we also demonstrate the rise in captive breeding and ranching is most likely due to changes in trade of the genera *Chameleo* in which captive breeding and ranching makes up almost two thirds of its exports globally. This captive breeding increase is a signifier of improved chameleon husbandry in traditionally importing nations, therefore although these captively bred individuals are still included in the CITES international trade data, it is likely captive breeding has led to greater unseen domestic trade in traditionally importing countries such as the USA where captive breeding is expanding to satisfy demand (Robinson et al, 2015).

Another reason for falling trade in *Chameleo* could be they are becoming less abundant in the wild. They are generally lowland species that are often found in disturbed habitats particularly farmland. There is little research on the effect of increasingly intensive farming methods on these animals, particularly in Africa, however it appears that chemical pollution from pesticides and herbicides can have significant effects on hatching rate in chameleons (Gómara et al, 2007) with pesticide misuse being a large problem across the continent (Williamson et al, 2008) and pesticide use increasing (De Bon et al, 2014) the impact on chameleons should be assessed in greater detail particularly in Africa. Indeed whilst interviewing villagers in the Kilombero valley they reported seeing chameleons far less than they used to and many postulated that pesticide was the reason they do not see them anymore.

The aforementioned imbalance in genera being captively bred also explains the stable volume of trade in *Kinyongia* and *Trioceros* and is expected as these species are notoriously difficult to breed in captivity (personal observations from online forum surveying) and very little is known about their husbandry. Many of the factors that make them challenging for captive breeders revolve around the replication of very specific habitat conditions they are used to as endemics and a lack of knowledge about their existence in the wild. Both of these factors hold true for many endemic species across the globe and again suggest a lack of detail in the global picture of captive breeding and merits further investigation. If it is the case, as this evidence suggests, that captive breeding only reduces the export of generalist, adaptable species then is it really that a trend to be celebrated as in previous research when endemic trade remains stubbornly high?

Demand was identified as being divided into two markets, the majority market dealing in mostly *Chameleo* and some *Trioceros* species and then a smaller hobbyist market for more 'exotic' less well known species. The more generalist market has a strong presence online with there being a variety of online marketplaces for *Chameleo* and *Trioceros* species. In the US the market is dominated by large businesses, 10 firms account for 72.3% of the reptile import market (Collis & Fenili, 2011) this big business landscape suggests that profitability is key in determining those species imported and explains the high numbers of

more easily sourced *Chameleo* species and *Trioceros*, both of which are perceived as easier to care for by pet owners than genera like *Kinyongia*. By comparison the specialist hobbyist market in range restricted species is comprised of smaller actors, often small family run reptile businesses and in the experience of this report with very little presence online which further frustrates efforts to understand threats to these specialist species. Knowledge of these sellers was based of infrequent comments left on online forums and Facebook pages and is not reliable data. Crossover between these markets is also possible due to misidentification which seems to be encountered not uncommonly in hobbyist circles, further exemplifying the unknown nature of the threats to cryptic species. Both online and physical markets for specialist animals need to be more thoroughly surveyed so that the trade can be more accurately mapped out by organisations such as CITES to improve protection of endemic species.

Aside from the international issues with permits and quotas mentioned earlier, this research also identified local issues with permits proving difficult to implement on the ground in such remote locations. While interviewing local people in the Eastern Arc Mountains knowledge of permits was very low, indeed almost no respondents had been shown permits before collecting chameleons, and in the few cases where they asked about permits they were told there was not an issue. Even if the quotas are accurately biologically determined, which this report casts doubt on, they are enforced much too far down the supply chain to be effective as the animals have already been removed from their habitats and transported in dangerous conditions where many die or are injured. If a system of quotas is intended to functionally protect a population the enforcement and understanding of them needs to be closer to the point of procurement than it currently is. The misunderstanding of CITES permits and quotas was also common among consumers. Even if buyers were inclined to ask for permits (which appears rare) they would be easily forged, or easy to claim the animals are captive bred. Additionally this research found negative opinions about CITES regulations expressed by hobbyists, this is similar to research in end consumers of CITES listed orchids and we reach similar conclusions that enforcement be more targeted on online trade, as these opinions are particularly worrying in hobbyist circles as they are the consumers of the most threatened species (Hinsley et al, 2016).

One of the most alarming aspects of studying the chameleon trade in Tanzania was the lack of awareness of the trade by the conservation network present in Tanzania; this was seen across the board from NGO's such as TRAFFIC, WWF and the UNDP (which works closely with locals in these areas) to government agencies and down to the level of park managers. Indeed even managers of established nature reserves, when asked prior to my survey, whether they were aware of the trade existing they said that they were not. This is alarming considering the volume of the trade and the long historic nature of it. Indeed in some cases the trade has spanned generations being passed from father to son. Whilst these reserve managers are well integrated into local communities it is perhaps a 'don't ask don't tell' arrangement on behalf of local people. Indeed following this report it is clear this network of nature reserves could be invaluable in ascertaining the scale of wildlife trading from remote areas such as these (Biggs et al, 2016). This could form part of a 'three strike' system

with CITES monitoring, national monitoring and community monitoring of trade in vulnerable species.

This research was conducted shortly after a national ban on all live animal exports from Tanzania was put in place and does provide evidence that the blanket ban appears momentarily successful in controlling the trade in chameleons. However it also provides strong evidence for the human cost such a ban on local people (Robinson et al, 2015). Additionally the continued effectiveness of such a ban long term is unlikely due to the nature of the trade observed during the course of this research. This report shows the role of endemics in Tanzanian trade and demonstrates there is global demand for Tanzania to participate in trading these animals. As Tanzania is the only source country for these animals and they are currently under such a restrictive export policy, it is likely, considering the ample evidence of black market trade being generated under these conditions, that this trade will move underground (Cooney & Jepson, 2006). Indeed national level bans in source countries are rarely effective long term and evidence shows they are usually followed by an increase in the illegal trade that is hard to eradicate, especially in nations that lack the capacity to deal with ever-more sophisticated crime rings that control illegal trade (Cooney & Jepson, 2006; Santos et al, 2011).

With a growing global reptile market, high demand for endemic species, the difficulty of the captive breeding sector to rear these animals, the financial costs to local communities of the blanket ban and the steady demand for these species this report finds ample evidence that a sustainable development project surrounding chameleons as a product would be successful in Tanzania and other source countries. Indeed it is important to bear in mind the global value of the reptile trade and how this is disproportionately centred in Europe and the USA (Engler and Parry-Jones 2007; Collis & Fenili, 2011). This report reveals the vast price inequality between the price paid to collectors and the final price charged to pet owners, making it a rich source of income for local people if they could be ranched successfully in-situ and marketed straight to consumers (Robinson et al, 2015) ranching whilst more ecologically sound would also insulate participants from the financial risks associated with wild collection (Robinson et al, 2018). The suggestion of ranching was put to collectors during surveying and was met with enthusiasm with every respondent surveyed expressing an interest in chameleon farming if training and resources were provided, demonstrating a suitability for this kind of project

The limitations of this study include the aforementioned live animal ban currently in place in Tanzania. The timing of this study in relation to the ban makes the trends identified for Tanzanian chameleon trade hard to forecast into the future and leaves much open to speculation. It also had the effect of interactions with government agencies and authorities being very brusque and often unhelpful as the official line was adherent to this policy. The silver lining is that respondents appeared more candid than expected as the trade was not ongoing at the time of study. Other limitations revolve around resources and time; if given more of both the study would have benefitted greatly from targeting more areas in Tanzania to get a more representative picture across the country and of all species,

additionally the study would have benefitted from being able to devote more time to attempting to piece together the value chain in country by identifying more middlemen and exporters as well as visiting reptile fairs in importing nations.

Looking forward this research sheds light on the need for reform of CITES policy, both in its responsiveness to fluctuations in trade and its approach to cryptic and endemic species trade. This can be achieved through structural changes to the species review process and increased investment in educating new market sectors such as primary collectors and end consumers, all of which would increase the effectiveness of wildlife trade management. It also provides further evidence that endemic species are more at risk in the modern reptile market than generalists. This study also suggests that more research is needed into the existence of a possible grey market, used to launder endemics, to understand the prevalence of this kind of route to market. To understand the effect on specific species within Tanzania a follow up study is needed covering more mountain ranges and including population surveys of chameleons.

In conclusion this study of global chameleon trade fills vital knowledge gaps highlighting the threat to East African genera in comparison to previous research, the role of Tanzania in the current global trade and how the threats differ between different nations and genera. We evaluate the impacts that methods such as captive breeding and ranching could have on the chameleon trade with consideration given to the different taxa involved and find the current and future impacts variable across different genera due to variability in demand and ease of implementation. In particular this study highlights the threat to endemic chameleons and endemic reptiles globally posed by the live animal trade. We identify inadequacies in the regulatory systems currently in place to protect these vulnerable taxa both in the international CITES project and in national approaches to collection and export of these animals. Possible areas of interest for future research include replicating trade surveys such as this for similarly endemic and cryptic taxa globally; work on the effectiveness of quota systems for the vulnerable species mentioned in this report, and the evaluation of ranching options for East African species to provide a path to sustainable development in these regions

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References

Alfino, S. and Roberts, D.L., 2019. Estimating identification uncertainties in CITES 'look-alike'species. *Global Ecology and Conservation*, *18*, p.e00648.

Auliya, M., 2003. Hot trade in cool creatures: a review of the live reptile trade in the European Union in the 1990s with a focus on Germany. *TRAFFIC Europe, Brussels, Belgium*.

Auliya, M., Altherr, S., Ariano-Sanchez, D., Baard, E.H., Brown, C., Brown, R.M., Cantu, J.C., Gentile, G., Gildenhuys, P., Henningheim, E. and Hintzmann, J., 2016. Trade in live reptiles, its impact on wild populations, and the role of the European market. *Biological Conservation*, *204*, pp.103-119

Biggs, D., Cooney, R., Roe, D., Dublin, H.T., Allan, J.R., Challender, D.W. and Skinner, D., 2017. Developing a theory of change for a community-based response to illegal wildlife trade. *Conservation Biology*, *31*(1), pp.5-12.

Burgess, N.D., Butynski, T.M., Cordeiro, N.J., Doggart, N.H., Fjeldså, J., Howell, K.M., Kilahama, F.B., Loader, S.P., Lovett, J.C., Mbilinyi, B. and Menegon, M., 2007. The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biological conservation*, *134*(2), pp.209-231.

Bush, E.R., Baker, S.E. and Macdonald, D.W., 2014. Global trade in exotic pets 2006–2012. *Conservation Biology*, *28*(3), pp.663-676.

Carpenter, A.I., Rowcliffe, J.M. and Watkinson, A.R., 2004. The dynamics of the global trade in chameleons. *Biological Conservation*, *120*(2), pp.291-301.

Carpenter, A.I., Robson, O., Rowcliffe, J.M. and Watkinson, A.R., 2005. The impacts of international and national governance changes on a traded resource: a case study of Madagascar and its chameleon trade. *Biological Conservation*, *123*(3), pp.279-287.

Challender, D.W., Harrop, S.R. and MacMillan, D.C., 2015. Understanding markets to conserve trade-threatened species in CITES. *Biological Conservation*, *187*, pp.249-259.

Collis, A.H. and Fenili, R.N., 2011. The modern US reptile industry. *Economic Analysis*.

Cooney, R. and Jepson, P., 2006. The international wild bird trade: what's wrong with blanket bans?. *Oryx*, *40*(1), pp.18-23.

De Bon, H., Huat, J., Parrot, L., Sinzogan, A., Martin, T., Malezieux, E. and Vayssieres, J.F., 2014. Pesticide risks from fruit and vegetable pest management by small farmers in sub-Saharan Africa. A review. *Agronomy for sustainable development*, *34*(4), pp.723-736.

Engler, M. and Parry-Jones, R., 2007. Opportunity or threat: The role of the European Union in global wildlife trade. *TRAFFIC Europe, Brussels, Belgium*.

Flecks, M., Weinsheimer, F., Böhme, W., Chenga, J., Lötters, S. and Rödder, D., 2012. Watching extinction happen: the dramatic population decline of the critically endangered Tanzanian Turquoise Dwarf Gecko, Lygodactylus williamsi. *Salamandra*, *48*(1), pp.12-20.

Gavin, M.C., Solomon, J.N. and Blank, S.G., 2010. Measuring and monitoring illegal use of natural resources. *Conservation Biology*, *24*(1), pp.89-100.

Gómara, B., Gómez, G., Díaz-Paniagua, C., Marco, A. and González, M.J., 2007. PCB, DDT, arsenic, and heavy metal (Cd, Cu, Pb, and Zn) concentrations in chameleon (Chamaeleo chamaeleon) eggs from Southwest Spain. *Chemosphere*, *68*(1), pp.25-31.

Harfoot, M., Glaser, S.A., Tittensor, D.P., Britten, G.L., McLardy, C., Malsch, K. and Burgess, N.D., 2018. Unveiling the patterns and trends in 40 years of global trade in CITES-listed wildlife. *Biological Conservation*, *223*, pp.47-57.

Hinsley, A., Nuno, A., Ri dout, M., John, F.A.S. and Roberts, D.L., 2017. Estimating the extent of CITES noncompliance among traders and end-consumers; lessons from the global orchid trade. *Conservation Letters*, *10*(5), pp.602-609.

Howell, K.M., 1996. 6. Mortality in Tanzania's bird trade. *The Live Bird Trade in Tanzania*, p.63.

IUCN 2019. *The IUCN Red List of Threatened Species. Version 2019-3*. http://www.iucnredlist.org. Downloaded on 16th of march 2020

Janssen, J. and Indenbaum, R.A., 2019. Endemic Vietnamese reptiles in commercial trade. *Journal of Asia-Pacific Biodiversity*, *12*(1), pp.45-48.

Jensen, T.J., Auliya, M., Burgess, N.D., Aust, P.W., Pertoldi, C. and Strand, J., 2019. Exploring the international trade in African snakes not listed on CITES: highlighting the role of the internet and social media. *Biodiversity and conservation*, *28*(1), pp.1-19.

Kideghesho, J.R., 2016. Reversing the trend of wildlife crime in Tanzania: challenges and opportunities. *Biodiversity and conservation*, *25*(3), pp.427-449.

Menegon, M., Loader, S.P., Davenport, T.R., Howell, K.M., Tilbury, C.R. and Machago, S., 2015. A new species of chameleon (Sauria: Chamaeleonidae: Kinyongia) highlights the

biological affinities between the Southern Highlands and Eastern Arc Mountains of Tanzania. *Acta Herpetologica 10*(2), pp 111-120.

Meng, H., Carr, J., Beraducci, J., Bowles, P., Branch, W.R., Capitani, C., Chenga, J., Cox, N., Howell, K., Malonza, P. and Marchant, R., 2016. Tanzania's reptile biodiversity: distribution, threats and climate change vulnerability. *Biological Conservation*, *204*, pp.72-82.

Di Minin, E., Fink, C., Tenkanen, H. and Hiippala, T., 2018. Machine learning for tracking illegal wildlife trade on social media. *Nature ecology & evolution*, *2*(3), pp.406-407.

Morgan, J. and Chng, S., 2018. Rising internet-based trade in the Critically Endangered ploughshare tortoise Astrochelys yniphora in Indonesia highlights need for improved enforcement of CITES. *Oryx*, *52*(4), pp.744-750.

Nijman, V. and Bergin, D., 2017. Reptiles traded in markets for medicinal purposes in contemporary Morocco. *Contributions to Zoology*, *86*(1), pp.39-50.

Olsen, M.T.B., Geldmann, J., Harfoot, M., Tittensor, D.P., Price, B., Sinovas, P.A.B.L.O., Nowak, K., Sanders, N.J. and Burgess, N.D., Thirty-six years of legal and illegal wildlife trade entering the USA. *Oryx*, pp.1-10.

Patrick, D.A., Shirk, P., Vonesh, J.R., Harper, E.B. and Howell, K.M., 2011. Abundance and roosting ecology of chameleons in the East Usambara Mountains of Tanzania and the potential effects of harvesting. *Herpetological Conservation and Biology*, *6*(3), pp.422-431.

Robinson, J.E., Griffiths, R.A., John, F.A.S. and Roberts, D.L., 2015. Dynamics of the global trade in live reptiles: Shifting trends in production and consequences for sustainability. *Biological Conservation*, *184*, pp.42-50.

Robinson, J.E., Griffiths, R.A., Fraser, I.M., Raharimalala, J., Roberts, D.L. and St. John, F.A., 2018. Supplying the wildlife trade as a livelihood strategy in a biodiversity hotspot. *Ecology and Society*, *23*(1).

Rovero, F., Menegon, M., FjeldsAa, J., Collett, L., Doggart, N., Leonard, C., Norton, G., Owen, N., Perkin, A., Spitale, D. and Ahrends, A., 2014. Targeted vertebrate surveys enhance the faunal importance and improve explanatory models within the Eastern Arc Mountains of Kenya and Tanzania. *Diversity and Distributions*, *20*(12), pp.1438-1449.

Sajeva, M., Augugliaro, C., Smith, M.J. and Oddo, E., 2013. Regulating internet trade in CITES species. *Conservation Biology*, *27*(2), pp.429-430.

Santos, A., Satchabut, T. and Vigo Trauco, G., 2011. Do wildlife trade bans enhance or undermine conservation efforts. *Applied Biodiversity Perspective Series*, *1*(3), pp.1-15.

Sabine Schoppe (2009). Status, trade dynamics and management of the Southeast Asian Box Turtle in Indonesia. *TRAFFIC Southeast Asia, Petaling Jaya, Selangor,* Malaysia pp.1-4

Sodeinde, O.A. and Soewu, D.A., 1999. Pilot study of the traditional medicine trade in Nigeria. *TRAFFIC bulletin- Cambridge- TRAFFIC INTERNATIONAL*, *18*, pp.35-40.

Stuart, B.L., Rhodin, A.G., Grismer, L.L. and Hansel, T., 2006. Scientific description can imperil species. *Science*, *312*(5777), pp.1137-1137.

Tilbury, C.R., 2010. *Chameleons of Africa: an atlas: including the chameleons of Europe, the Middle East and Asia*. Edition Chimaira.

Tolley, K.A. and Herrel, A., 2013. *The biology of chameleons*. Univ of California Press.

Tolley, K.A. and Menegon, M., 2013. Evolution and biogeography of chameleons. *The biology of chameleons*, pp.131-150.

Vaglica, V., Sajeva, M., McGough, H.N., Hutchison, D., Russo, C., Gordon, A.D., Ramarosandratana, A.V., Stuppy, W. and Smith, M.J., 2017. Monitoring internet trade to inform species conservation actions. *Endangered Species Research*, *32*, pp.223-235.

Williamson, S., Ball, A. and Pretty, J., 2008. Trends in pesticide use and drivers for safer pest management in four African countries. *Crop protection*, *27*(10), pp.1327-1334.

Xiao, Y., Guan, J. and Xu, L., 2017. Traffic Wildlife Cybercrime in China. *TRAFFIC*.