



Exploring the international trade in African snakes not listed on CITES: highlighting the role of the internet and social media

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Abstract

Globally, there is an extensive trade in snakes for pets, especially in the European and North American markets. This trade includes many African snakes, but few of these are present on CITES appendices, suggesting little regulation of this international trade. In this study, we assess the status of this unregulated trade, by analyzing export lists and private seller advertisements, collected by correspondence, monitoring and recording social media and online forums. Furthermore, by engaging with African exporters, we map the distribution of trading hubs involved in the international trade of African snakes. We show that the African snake trade is extensive and involves rare and range-restricted species, including species on the IUCN red list of threatened species. Furthermore, the internet and social media are shown to play an increasing role in the trade of exotic reptiles. We found 2.269 wild caught live African snakes from 42 species, present in 15 African countries, to have been advertised for sale between 2013 and 2017. Traded species were predominately venomous and the 23 most traded species were not CITES listed. Three main hubs for the live snake trade occur on the African mainland: Tanzania, Togo, and Egypt. By using publicly available data we demonstrate an extensive trade in snake species where basic biological knowledge and conservation status is often missing and the sustainability of this trade is questionable. To tackle this potentially detrimental trade we recommend detailed investigations aiming to understand current threats to snakes, especially focusing on species not regulated by international conventions.

Keywords Unregulated harvest · CITES · Pet trade · Reptile · IUCN red list

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Introduction

Reptiles are exotic and popular pets, especially in Europe and the USA (Auliya 2003; Robinson et al. 2015; Auliya et al. 2016). The snake species traded within the pet industry often are dangerous due to their venom, have spectacular looks, colors, or are rare in the wild (Auliya et al. 2016). These criteria are represented in many African snake species, which explains their capture in considerable numbers for the international pet trade.

Mainland Africa supports at least 571 snake species (Uetz 2016), and many of these species are threatened by anthropogenic processes and human-induced exploitation (Schlaepfer et al. 2005; Meng et al. 2016; Tolley et al. 2016). African snakes are not only exploited for the pet trade, there is also an extensive international trade in skin and leather products, involving *Python sebae* and *Python regius* (Luiselli et al. 2012), along with domestic trade in snake meat—particularly in West and Central Africa (Hardi et al. 2017; Jensen 2017).

The capture of specific reptile species for the pet trade is currently regarded as the second largest threat to their populations across the world (Böhm et al. 2013). This demand may particularly impact range-restricted species (Sodeinde and Soewu 1999; Schlaepfer et al. 2005; Auliya et al. 2016) especially if sourced from the wild, or when these are claimed as captive-bred or farmed in facilities that operate with little supervision (Bush et al. 2014; Annorbah et al. 2016). Collecting and trading wildlife is an income-generating activity for some households in developing countries (Roe 2002). In West Africa, collecting reptiles destined for the international pet trade has also become an enterprise, primarily in Ghana, Benin, and Togo where Ball pythons, *Python regius*, have been ranched and exported by the millions (Toudonou 2015).

International conservation conventions exist to discuss, develop, and provide guidelines for the sustainable use of biological resources, with the aim to conserve biological diversity. The Convention on Biological Diversity (CBD, entered into force on 29 December 1993), and The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, entered into force on 1 July 1975) contain 194 and 183 member countries respectfully. CITES is specifically aimed at the protection and regulation of species involved in the international commercial wildlife trade. Globally, approximately 90% of reptile species are not regulated by CITES (Auliya et al. 2016), with only 12 of the 571 species of African snakes being regulated by CITES (Jensen 2017). This mainly includes Pythonidae spp. and Boidae spp. (*Calabaria*, *Eryx*), of which the ball python (*Python regius*) dominates in terms of trade volume (Robinson et al. 2015).

Few studies show the extent of trade in non-CITES listed reptiles destined for the European and North American markets, which are known to be major players in the trade of CITES, and non-CITES listed reptile species (Auliya 2003; Carpenter et al. 2004; Auliya et al. 2016; Jensen 2017). Reptile fairs, particularly in Germany and the Netherlands, are known hubs for the sale and distribution of non-CITES reptiles (Altherr 2014). However, the increase of social media and online trading has created a larger number of platforms for trading wildlife legally, and illegally (Morgan and Chng 2017; Bergin et al. 2018). The use of internet auction sites as sales platforms for non-CITES species has recently been shown to be of increasing global concern (Sajeva et al. 2013; Vaglica et al. 2017; Sy 2018).

In addition to potentially unsustainable harvests triggered by international demand, threatening the long-term viability of species and wild populations, animal welfare, the transmission of zoonotic diseases, fungal pathogens, and the introduction of invasive species have all caused concern in relation to the reptile trade (Karesh 2005; Westphal et al. 2007; Baker et al. 2013). In recent years the emergence of a snake fungal disease (SFD)

caused by *Ophidiomyces ophiodiicola* (Lorch et al. 2016; Franklino et al. 2017) has raised alarming concerns with scientists as well as national authorities with the prospects of a new conservation disaster, similar to the mass mortalities caused by the chytrid fungus in amphibian populations (Altmann and Kolby 2017). The welfare of wildlife traded for the international pet trade is in need of intensified and focused research (Rosen and Smith 2010) as it is often neglected and not prioritized (Baker et al. 2013) with poor transport conditions and disease resulting in unknown mortality rates.

In this paper, we use a novel approach to monitor and analyze online-based trade and advertisements for wild-caught African snakes available on publicly available sources. By highlighting trade in species not assessed by the IUCN Red List and CITES, we show the need for relevant data on wildlife exploitation, and underlying life history traits, population and distribution data, which are to be considered essential for policymakers to develop and implement relevant regulations. Further, we show that online trade analyses must be incorporated into the conservation assessment, to monitor new trading venues where wildlife exploitation occurs.

Methods

Data collection

To investigate the trade in live wild African snakes we analyzed online sales venues by systematically visiting social media groups and forums containing advertisements. We recorded sale advertisements for live, wild-caught African snakes between 2013 and 2017. Between September 2016 and December 2017 searches were conducted at least once per week resulting in a minimum of 68 search queries containing the filtered keywords listed below. Data were captured using a simple approach of recording individual snakes from advertisements and removing duplicates from different sales groups to eliminate double counting. We collected data from one social media platform, Facebook and five online forums (Table 1). For each website and social media group we filtered the following keywords, excluding CITES-listed *Python*, *Eryx*, *Calabaria* and species difficult to capture/keep due to specific natural history traits, *Afrotyphlops*, *Indotyphlops*, *Leptotyphlops*, *Rhinotyphlops*, *Namibiana* following Uetz (2017): *Amblyodipsas*, *Amplorhinus*, *Aparallactus*, *Aspidelaps*, *Atheris*, *Atractaspis*, *Bitis*, *Boaedon*, *Bothrophthalmus*, *Buhome*, *Causus*, *Chamaelycus*, *Crotaphopeltis*, *Dasypeltis*, *Dendroaspis*, *Dipsadoboa*, *Dipsina*, *Dispholidus*, *Duberria*, *Echis*, *Elapsoidea*, *Eryx*, *Gonionotophis*, *Grayia*, *Hapsidophrys*, *Hemachatus*, *Hemirhagerhis*, *Homoroselaps*, *Hormonotus*, *Hydraethiops*, *Inyoka*, *Lamprophis*, *Lycodonomorphus*, *Lycophidion*, *Macrelaps*, *Macrovipera*, *Meizodon*, *Montaspis*, *Myriopholis*, *Naja*, *Natriciteres*, *Philothamnus*, *Polemon*, *Prosymna*, *Psammophis*, *Psammophylax*, *Pseudaspis*, *Pseudohaje*, *Pythonodipsas*, *Rhamnophis*, *Rhamphiophis*, *Scaphiophis*, *Telescopus*, *Thelotornis*, *Thrasops*, *Toxicodryas*, *Xenocalamus*. We queried genera in combination with the terms “wild caught”, “(WC)”, and “sale”. In this study, we were only interested in wild-caught animals, as these can directly be inferred to be taken from the wild. We discarded “farm raised” or “ranchd” animals due to the controversy involved with this label which involves both animals bred by humans, but also the potential laundering of wild animals as captive-bred. The following four attributes were recorded for snakes offered for sale: (1) offering price (converted to US\$ 25/06/2017 using exchange rate 1 US \$ = 0.89

Table 1 List of sales venues analyzed for this study

Websites	Facebook groups	Facebook groups web address	Facebook group members (March 2017)
www.kingsnake.com/	Hamm and Houten reptile classifieds	https://www.facebook.com/groups/242,866,079,189,494/	16,394
www.terrarisik.com/	International trade for venomous snakes	https://www.facebook.com/groups/venomoussnakes/?fref=ls	2353
www.faunaclassifieds.com/	Venomous reptiles for Hamm/Houten	https://www.facebook.com/groups/1733573043621851/?fref=ls	145
www.venomousreptiles.org	Hamm and Houten reptile classifieds	https://www.facebook.com/groups/227359864061887/?fref=ls	670
www.deineterwelt.de	Venomous snakes lounge: for sale/buy/trade	https://www.facebook.com/groups/Venomous.Snake.Lounge/?fref=ls	7400
	Venomous reptile sale trade and Nfs	https://www.facebook.com/groups/377748088985204/	66
	Venomous reptile classifieds	https://www.facebook.com/groups/360560250675015/	4739
	Importers and exporters of live reptiles, Birds small animals, and mammals	https://www.facebook.com/groups/1467651233465197/?fref=ls	1474

The list contains five forums from where snakes and other wildlife is advertised for sale. Eight Facebook groups were investigated for sales advertisements and recordings were made on advertisements dating back to 2013. Direct link to Facebook groups are listed as well as the number of members recorded March 2017

EUR); (2) seller location [recorded as country]; (3) animal origin [country of origin as listed by seller]; and (4) quantity for sale. Queries were only conducted in English. To maintain the anonymity of sellers involved in the trade of African snakes, we removed names and any publicly available data that might be associated with the advertisements before conducting the analysis.

The online sales venues investigated for this analysis were easily accessible. Social media were evaluated as a trading venue and Facebook was found to contain several sales groups. Some groups were closed but an invitation allowed access to advertisements. Eight Facebook groups were found to specialize in reptile trade, and five international websites contained forums where trade in reptiles was found (List of venues analyzed see Fig. 1).

Online advertisements usually display the source of the animal advertised for sale. The terms most commonly used are wild caught (WC), captive-bred (CB, NZ, the German acronym for “Nachzucht”), captive-born and bred (CBB), farm-bred (FB), captive-hatched (CH), and long-term captive (LTC). For this analysis, we were only interested in wild-caught snakes. Due to fragility and potential low survival rate, wild-caught animals often have lesser value than those offered as captive-bred. In this analysis, advertisements that excluded information on the source have been considered wild-caught.

We contacted exporters from 21 African countries (Togo [4], Tanzania [4], Benin [1], Democratic Republic of Congo [1], Nigeria [1], Egypt [5], Sudan [1], Kenya [1], Cameroon [1] and the Republic of Congo [1], Guinea [1]). Contact was made through email, impersonating a potential buyer and requesting stock and price lists (see online annex for complete stock/price lists and company information). During the process, no attempts were made to encourage the capture of wild snakes and, to avoid this we specifically asked only for price lists and stocklists. Geographical location of the exporters was extracted from stock/price lists and personal correspondence, which contained business information (e.g. address, ownership). Prices from exporter lists on species were recorded. We compared the prices from exporter lists to prices from online sales advertisements from private sellers to identify most valuable species.

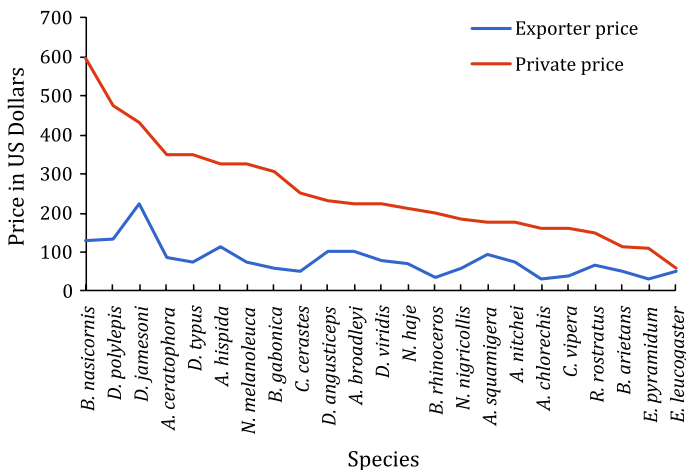


Fig. 1 Recorded sales prices in USD for the 23 most recorded species for sale. Blue lines indicate average asking price from exporters recorded from stock/price lists. Red lines indicate average sales prices as advertised on online sales venues by private sellers. Species are listed from most expensive to the least expensive as advertised by private sellers

To establish the coverage of national legislation protecting and regulating trade, and source countries involved in high levels of trade in non-CITES African snakes, we reviewed national legislation pertaining to snakes. By searching “snakes” and “reptiles” in combination with the following geographical regions (Tanzania, Kenya, Cameroon, Togo, Nigeria, Egypt) on the ECOLEX website (www.ecolex.org) we managed to extract information on snake legislation and regulations.

Results

Species traded

Between 2013 and 2017, we identified 2,269 live African snakes in online sales advertisements, covering 42 species. The genera most commonly recorded were *Atheris*, *Bitis*, *Naja*, *Dispholidus*, and *Dendroaspis* (see the full list in online annex Table S1). We used the most frequently recorded species for further analysis (more than 20 recordings of individuals per species) which resulted in 23 most frequently traded African non-CITES listed snakes (Table 2). Eight of these 23 species have been assessed in the IUCN Red List (one Vulnerable [VU], and seven Least Concern [LC]). Among these 23 species, 60,8% (n=14) are Viperidae spp., 30,4% (n=7) are Elapidae spp. and 8,6% (n=2) are Colubridae spp. The species include the Usambara bush viper, *Atheris ceratophora*, a Tanzanian endemic of the Eastern Arc Mountains, assessed as VU by IUCN (Phelps 2010; Menegon et al. 2014). This was the most frequently recorded *Atheris* species (n=148) offered for sale during this study. The East African endemics such as the great lakes bush viper *Atheris nitschei* (n=85) (see Menegon et al. 2014), and the Eastern green mamba *Dendroaspis angusticeps* (n=61) were also frequently advertised. Common West African endemics advertised included the West African Gaboon adder *Bitis rhinoceros* (n=117) (see Penner et al. 2008), the Western bush viper *Atheris chlorechis* (n=32) (see Phelps 2010), and the Western green mamba *Dendroaspis viridis* (n=45) (see Dobiey and Vogel 2007). North African endemics were represented by the Sahara horned viper *Cerastes cerastes* (n=49), and the Sahara sand viper *Cerastes vipera* (n=38). The advertisements did not only include localised endemics, but also species with more extensive distribution ranges in Africa; the most frequent recorded species offered for sale was the East African Gaboon viper *Bitis gabonica* (n=235), the puff adder *Bitis arietans* (n=101), the black mamba *Dendroaspis polylepis* (n=51), and the nose-horned viper *Bitis nasicornis* (n=233) (see Phelps 2010).

Of the seven species of Least Concern [LC], three species have been advertised in Ghana, two species in Uganda, Tanzania, Cameroon, Ivory Coast, Niger and one species in Togo.

Prices

The prices of snakes advertised for sale were divided into prices reported in exporter stocklists, and prices indicated by private sellers and importers (Fig. 1). Lowest exporter prices were recorded in West Africa i.e. *A. chlorechis* US\$30, *Bitis* spp. US\$20–30, and the North-eastern carpet viper *Echis pyramidum* US\$30, whilst highest exporter prices were found in East Africa i.e. *D. polylepis* US\$170, Jameson’s green mamba *Dendroaspis jamesoni* US\$150, and *B. nasicornis* US\$230. The five most valuable species (species demanding

Table 2 The 23 most recorded species of African snakes in this analysis between 2013 and 2017

Most frequently recorded non-CITES African snakes for sale on online trading venues							
Species recorded	Common names	Number of recordings	IUCN assessment*	Assessment year	Range states	Location extracted from exporters	Location extracted from private sellers
<i>Atheris ceratophora</i>	Usambara horned viper	148	VU	2009	TZ	TZ	TZ
<i>Atheris squamigera</i>	Variable bush viper	139	NE	–	KE, UG, CF, CM CD, CG, GA, AO, TG, GH, NG	CD, CM, TZ	CD, CM, TZ, UG
<i>Atheris chlorechis</i>	Green bush viper	32	LC	2012	GN, SL, LR, CI, GH, TG, NG, CM	TG, GN	GH
<i>Atheris hispida</i>	African hairy bush viper	45	NE	–	CD, UG, KE, TZ	CD, TZ	CD, CM, TZ, UG
<i>Atheris nitschei</i>	Great lakes bush viper	85	NE	–	TZ, UG, CD, RW, BI, MW, ZM	CD, TC, TZ	UG, TZ
<i>Atheris broadleyi</i>	Broadleys bush viper	18	NE	–	CM, CF, NG, CG	CM	CM
<i>Bitis nasicornis</i>	Rhinoceros viper	233	NE	–	SD, KE, UG, AO, CD, CG, GA, CM, GQ, NG, BE, TG, GH, CI, LR, SL, GN, CF, TZ, ZM	CD, NG, GN, CM	CI, GH, UG, BN, CG
<i>Bitis gabonica</i>	Gaboon viper	235	NE	–	BE, NG, TD, CF, CM, UG, GQ, CG, CD, AO, ZM, KE, RW, GA, TZ, ZW, MZ, ZA, MW, TG	CD, TG, NG, TZ, GN, CM	GH, CG, CM, UG, TZ
<i>Bitis rhinoceros</i>	Nose horned viper	117	LC	2012	GN, GW, LR, SL, CI, GH, TG	TG, GN	TG, CI, GH
<i>Bitis arietans</i>	Puff adder	101	NE	–	Pan-African	CD, TG, NG, TZ, GN, CM	NA, KE, TZ, CD, TG

Table 2 (continued)

Most frequently recorded non-CITES African snakes for sale on online trading venues							
Species recorded	Common names	Number of recordings	IUCN assessment*	Assessment year	Range states	Location extracted from exporters	Location extracted from private sellers
<i>Dendroaspis polylepis</i>	Black mamba	51	LC	2009	AO, BW, BF, CF, ER, CI, SN, GN, GW, ML, CM, ET, CI, KE, MW, MZ, NA, ZA, SO, SZ, TZ, UG, CD, ZM, ZW	TZ, GN	UG, TZ, CM
<i>Dendroaspis viridis</i>	Western green mamba	45	LC	2012	GM, SN, GN, GW, LR, CI, GH, SL, BE, CF, TG, NG	TG, NG, GN	GH
<i>Dendroaspis jamesoni</i>	Jameson's mamba	102	NE	–	GH, TG, NG, CM, GN, GA, BE, CF, CD, CG, KE, UG, RW, BU, GQ, AO, SD, ZM	CD, CM, TZ	CM, UG, CG, TZ
<i>Dendroaspis angusticeps</i>	Green mamba	61	NE	–	KE, TZ, MZ, MW, ZW, ZA, CD	TZ	TZ, KE
<i>Rhamphiophis rostratus</i>	Rufous beaked snake	129	NE	–	ZA, SD, ET, MZ, SO, KE, UG, TZ, MW, ZW, ZM	TZ	TZ
<i>Dispholidus typus</i>	Boomslang	61	NE	–	NA, BW, ZW, ZA, SW, MZ, NG, CM, CF, UG, BI, RW, MW, KE, TZ, CD, CG, AO, ZM, SN, ER, ET, SO, ML, CI, GM, BE, TG, SL, GN, LR, GH, BF	TZ	TZ, UG, CM, TG
<i>Cerastes vipera</i>	Sahara sand viper	38	LC	2012	EG, LY, TN, DZ, MA, MR, ML, NE, EH	EG	EG

Table 2 (continued)

Most frequently recorded non-CITES African snakes for sale on online trading venues							
Species recorded	Common names	Number of recordings	IUCN assessment*	Assessment year	Range states	Location extracted from exporters	Location extracted from private sellers
<i>Cerastes cerastes</i>	Desert horned viper	49	NE	–	EG, LY, TN, DZ, MA, MR, ML, NE, SD, EH	EG	EG, MA
<i>Echis leucogaster</i>	White bellied carpet viper	26	LC	2012	BF, ML, DZ, NE, NG, MR, EH, SN, GM, TD, MA	TG	NE
<i>Echis pyramidum</i>	North east African carpet viper	53	LC	–	KE, SO, ET, TN, LY, EG, DJ, ER, UG, SD, CF	EG	EG
<i>Naja melanoleuca</i>	Forest cobra	36	NE	–	AO, BE, BF, CM, CF, TD, CD, CG, ET, GA, GH, GW, GM, GN, CI, KE, LR, MW, ML, MZ, NE, NG, ZA, SN, SL, SO, SD, TZ, TG, UG, ZM, ZW	TZ, GN	GH, CD, TZ, CM
<i>Naja nigricollis</i>	Black-necked spitting cobra	30	NE	–	AO, BE, BF, CM, CF, TD, CD, CG, ET, GA, GH, GW, GN, CI, KE, LR, ML, NE, NG, SN, SL, GM, AR, SD, TZ, SO, TG, UG, ZM	EG, TZ, GN	TZ
<i>Naja haje</i>	Egyptian cobra	84	NE	–	DZ, BF, CM, CF, CD, TD, EG, ER, GW, GN, KE, LY, ML, EH, MR, MA, NE, NG, SN, SO, SD, TZ, UG, ZW	EG, TZ	EG, TZ

Table 2 (continued)

Most frequently recorded non-CITES African snakes for sale on online trading venues							
Species recorded	Common names	Number of recordings	IUCN assessment*	Assessment year	Range states	Location extracted from	Location extracted from private sellers
<i>Total</i>							
1918							

The analysis compiled 1918 animals advertised for sale on online platforms. The list consists exclusively of venomous species and their IUCN red list status is shown. Range states are shown as country codes. The “exporter” column shows which countries snakes were available from exporters, and the “Origin for animals privately advertised” column shows countries from where animals are labeled to origin from when advertised by private sellers

the highest price by private sellers) include *B. nasicornis*, *D. polylepis*, *D. jamesoni*, *A. ceratophora* and the Boomslang *Dispholidus typus*.

Trading venues

A total of 111 Facebook advertisements and 55 online fora were recorded and analyzed. Both text-based advertisements and those containing pictures were recorded without differentiation. In both Facebook and on online fora, we found an increase in advertisements of wild-caught African snakes from 2013 to 2017. Facebook advertisements steadily increased starting with three advertisements in 2013 to 34 in 2017 (Fig. 2). The number of advertisements recorded from online forums was steady in 2013, 2014 and 2015 with four to five advertisements, with a steep increase in 2016 and 2017—involving 19 and 22 advertisements, respectively (Fig. 2).

Trading routes and hubs

Private sellers and importers offering African snakes for sale online are primarily found in North America and Europe, e.g., the USA ($n=24$), Germany ($n=23$), the Czech Republic ($n=6$), the Netherlands ($n=5$) and France ($n=3$). Other European sellers are located in Slovenia, Portugal, Luxembourg, Sweden, Belgium, Switzerland, and Spain.

A total of 21 African exporters have provided stock lists and price lists on available species, showing that they are concentrated in three countries offering snakes from different biogeographic regions: West Africa (Togo), East Africa (Tanzania) and Northeast Africa (Egypt) (Fig. 3). These hubs were designated by the number of exporters found by direct contact. Three or more exporters indicate a certain level of international trade and is therefore classified as a hub in this study. Our analysis traced several other exporters dispersed throughout Africa; for example in Cameroon, Sudan, Kenya, Republic of Congo, the Democratic Republic of Congo and Guinea.

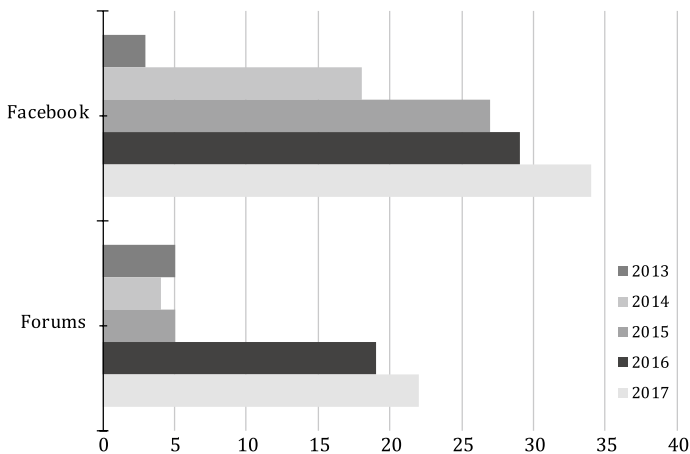


Fig. 2 The number of advertisements recorded from Facebook and from online forums between 2013 and 2017

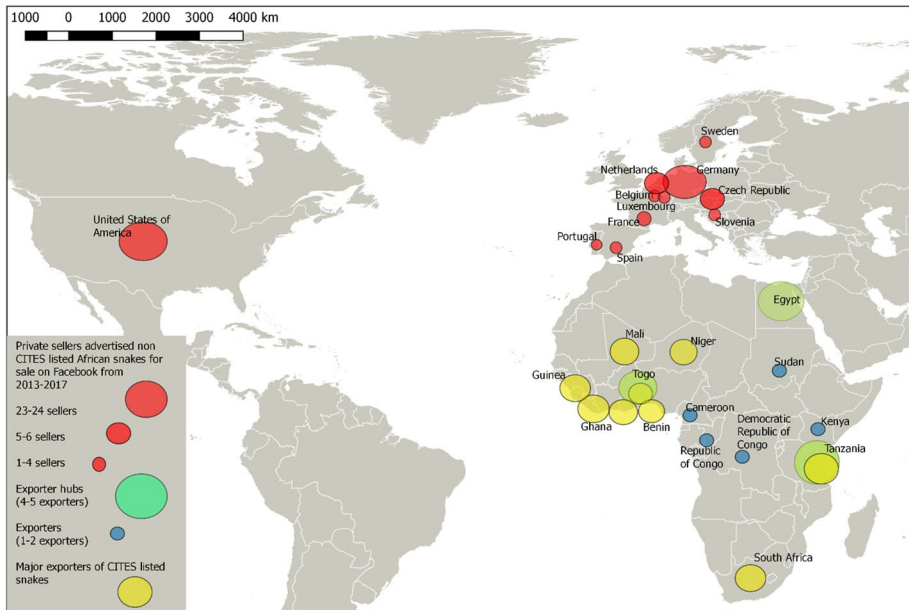


Fig. 3 Locations of exporters and private sellers. Red dots show private sellers advertising non-CITES African snakes for sale on Facebook. Green dots show exporter hubs in Africa exporting non-CITES-listed snakes. Blue dots indicate single exporters, not forming hubs. Yellow dots indicate major exporters of CITES-listed snakes destined for the international pet trade

Four exporters in Togo are known from previous research into the trade of the ball python (Harris 2002). These four companies had 23–41 reptile species readily available, including several non-CITES listed species i.e. *Bitis rhinoceros*, *B. nasicornis*, *B. arietans*, *A. chlorechis*, *D. viridis*, the black-necked spitting cobra *Naja nigricollis*, and the forest cobra *N. melanoleuca*. Other exporters of these species are located in Ghana and Benin (Reed 2005), however, communication proved unsuccessful during this study.

Our analysis also found 14 East African reptile exporting companies listed on official trading websites, but of these only four were responsive to approaches. They provided extensive price lists as well as photographic material for validation of business and quality of animals. Three exporters were located in Dar es Salaam, the largest city in Tanzania, and one in Muheza, close to the Kenyan border. The exporters listed the availability of 30 reptile species, including 12 of the non-CITES listed snakes included in this analysis: The variable bush viper *A. squamigera*, *Atheris ceratophora*, *A. nitschei*, *B. arietans*, *B. gabonica*, *B. nasicornis*, *D. polylepis*, *D. angusticeps*, *D. typus*, *N. melanoleuca*, *N. nigricollis* and the Egyptian cobra *Naja haje*.

Five of nine registered Egyptian exporters shown to be actively trading reptiles are located in Cairo and Giza, providing easy access to an international airport. The exporters offered several species of North African snakes including *Cerastes cerastes*, *C. vipera*, the painted carpet viper *Echis coloratus*, *N. haje* and *N. nigricollis*.

National legislation covering the trade in non-CITES snakes was prevalent in several of the implicated countries. In Kenya, the Wildlife Conservation and Management Act (2013) protects several species found in the international pet trade, including- *A. hispidus*,

A. squamigera, *B. gabonica* and *B. nasicornis*. Tanzania's Forest Resources Management and Conservation Act (1996), lists three species of snakes as having the highest level of protection, and 18 species of snakes to have the second highest protection, none of which were identified during this study. Five species are listed as having no protection - *D. angusticeps*, *D. typus*, *N. melanoleuca*, *Naja mossambica*, and *N. nigricollis*. Nigeria's Endangered Species Act (1985), protects and regulates the harvest of *Python sebae* and *Python regius*. Egypt's "law 4", protects specific reptiles, including CITES listed *Eryx colubrinus* and *Eryx jaculus*, none of which were found to be wild caught in this study. In Cameroon, ten species of snakes are protected under "Class B in the Order No. 0648/MINFOF (2006)" and can only be harvested and collected with a valid license. This includes *N. nigricollis*, *N. haje*, and *N. melanoleuca*.

Discussion

Here we show the existence of significant trade in African snakes, that is not regulated or monitored by CITES. We found 2,269 individual snakes, from 42 species listed for sale on online sales venues. The targeted species were traded online from several European countries and the USA. Three trading hubs were found to supply the international pet trade with non-CITES African snakes, these were Togo, Egypt, and Tanzania.

CITES and non-CITES listing

The 23 species of wild African snakes most frequently observed for sale were exclusively venomous species, and none are listed in the appendices of CITES. This study shows that the absence of CITES listings does not equal absence of trade, even for species that are assessed as threatened with extinction on the IUCN Red List. The presence of international trade could potentially affect wild populations, particularly in range-restricted species that have attracted international demand. Among mainland Africa's more than 570 snake species, 12 are listed on the appendices of CITES, of which 10 species represent boas and pythons (Jensen 2017). None of the African cobra species (*Naja* spp.) are listed on the appendices of CITES as opposed to the 13 Asian *Naja* spp. that are included in Appendix II of CITES (CITES 2017). Among African vipers, two were only recently listed i.e. *Bitis worthingtoni* and *Atheris desaixi*, both on CITES App. II in January 2017 (CITES 2017; European Union, <http://eur-lex.europa.eu>, 1998–2018—accessed on 2 July 2017). During the 28th CITES Animals Committee Meeting, a document reporting on "snake trade and conservation management (*Serpentes* spp.)" (<https://cites.org/sites/default/files/eng/com/ac/28/E-AC28-14-03.pdf>) based on IUCN Red List assessments of Asian snake species (DECISION 16.104), was launched. In this document, 115 Asian non-CITES snake species assessed in the IUCN Red List was filtered that occur in international trade. This endeavor was initiated during CITES CoP 15 (<https://cites.org/sites/default/files/eng/cop/15/doc/E15-48.pdf>), highlighting the need for more detailed in situ research (e.g., biology, distribution, exploitation levels, national legislation) and also evaluating adaptive management measures for the purpose of a precautionary approach. It is strongly recommended to adopt these recommendations to snake species of the African continent, in view of the fact that this reptile suborder, in particular, has been clearly neglected. Timely studies could, therefore, shed light on the threat status of various species in order to determine a CITES listing, to regulate trade between range states for varying purposes and to countries abroad.

Trading venues and the most popular species

This study only examined online venues from where snakes are advertised and sold. Another popular venue for trading snakes and other reptiles in Europe and USA are reptile fairs (Altherr 2014). Previous studies demonstrate that reptile fairs, such as the world's largest fair in Hamm, Nordrhine Westfalia (Germany) offer and sell a significant number of non-CITES reptile species, including members of the African snake genera *Atheris* and *Bitis* (Altherr 2014). *Atheris ceratophora* is the most recorded member of the *Atheris* family and its localized distribution must be considered an unfavorable trait if collection for the international pet trade is not appropriately monitored; offtake levels are therefore considered a potential threat to natural populations. The species has been assessed VU (Spawls and Joger 2010). Two *Bitis* species are also the most often recorded for sale in this study, *B. gabonica* and *B. nasicornis*. Both species are not assessed in the IUCN Red list which may be due to the challenge of the species' extensive geographic range, and status data are simply non-existent. However, a persistently targeted harvest in local populations of a wide-ranging species can decrease populations dramatically, increase fragmentation as well as reduce gene flow (Allendorf et al. 2008; Auliya et al. 2016).

Trade networks and trade dynamics

The location data obtained from analyzing online private sales advertisements indicates trading dynamics for snakes exported from Africa. Given that the USA and Germany most frequently advertise snakes for online sales, a considerable responsibility needs to be assigned to both countries, representing major consumers of non-CITES listed African snakes.

Major airports and border crossings can facilitate large volumes of trade but smaller, less informal road networks are also utilized by traders (Hansen et al. 2012). Wildlife is believed to be traded and distributed through so-called "hubs" (Nijman 2010), places where several traders/exporters are found in close proximity (Karesh 2005). West Africa is a well-known reptile exporting region and recognized as the second most prolific reptile exporting region in the world (Auliya et al. 2016), especially in the trade of *P. regius*. The four exporters from Togo form the West African hub in reptile trade and have previously been shown to be responsible for supplying roughly 90% of the *P. regius* trade out of Togo (Segniagbeto 2016). In East Africa, Tanzania represents the major exporter of reptiles as well as other taxa (Leader-Williams and Tibanyenda 1996; Robinson et al. 2015). Interestingly, according to the CITES trade data, South Africa has a substantial export of CITES-listed reptiles, but we found no evidence of wild snakes originating from South Africa advertised for sale online. However, trade in South African range-restricted vipers have been found sourced as captive-bred, these include *Bitis rubida*, *Bitis caudalis*, *Bitis armata* and *Bitis cornuta* [a species that previously contained *B. rubida*, *B. armata*, *B. albanica* and *B. inornata*, but have now all been elevated to full species (Graham and Marais 2007)].

There is growing evidence, that social media platforms are becoming increasingly involved in trade and exploitation of wildlife. However, data from social media have limitations that must be taken into consideration. The credibility of the information advertised by the sellers is possibly the biggest limitation. Information such as source, subspecies, and locality are recorded based solely on seller testimonies. Images attached to the advertisements add more credibility to the information, however, these can easily be falsified.

Advertisements on social media are dynamic in nature as they can be easily removed which limits the obtainable information and we are therefore only obtaining a snapshot of an existing trade. Analysing the use of social media for advertising the sale of snakes show an increase in snake advertisements on both forums and Facebook from 2013 to 2017. Using this information when analyzing and predicting future exploitation in wildlife is valuable in the pursuit of understanding trading dynamics and trade routes.

National legislation

National legislation in Africa, pertaining to snakes is scarce and seldom reflect contemporary trends in exploitation. Kenyan national legislation is successful in protecting species found in the pet trade, as none of the nationally protected species were recorded in this study. Tanzanian national legislation covers several snake species, none of which are found in the international pet trade. This could imply that national legislation directed towards local species is successful in protecting such species. This is further evident in the recorded trade in the five species without protection. National legislation in Nigeria, Egypt, Cameroon, and Togo is insufficient, as extensive trade in species sourced from these countries is recorded in this study.

Transport mortality, zoonotic disease, and human health implications

We provide temporal information on volumes of trade and trading routes influencing African reptile diversity. However, the extent of traded animals recorded in this analysis is regarded as a bare minimum as several factors are unaccounted for. Transport mortality is an almost completely unaddressed issue; one study conducted in 1996 (Steinmetz et al. 1998) demonstrates that up to 33% of reptiles may die during international transportation. The study further indicated that importers claimed similar losses within the first three days after arrival. One comprehensive study by Robinson et al. (2015) focused on mortality rates of reptiles kept for pets in the UK, and mortality rates of 7.6% of wild-caught/captive or farmed snakes ($n=21$) kept for pets were reported within the first year of acquisition. Another study investigating mortality in animal importers and wholesalers report mortality rates of 28.6% ($n=1.681$) in a single case of a North American wholesaler (Ashley et al. 2014). Accounting for these mortality rates could potentially indicate a much larger number of African snakes exported to Europe and USA. Besides, there is no information on mortality rates of species from the point of harvest to the exporter's premises, before being shipped abroad. Serious human health implications are linked to the observed unregulated trade in African snakes. The number of venomous species is alarming as potential bites can inflict serious damage to the pet keepers and can potentially result in death. In Europe, Germany and Southern France, 155 bites have been recorded from 1996 to 2006 (Schaper et al. 2009). In the United States from 1977 to 1995, 54 cases of bites from non-native venomous snakes were recorded (Minton 1996), and from 1995 to 2005—175 venomous bites (Warrell 2009) Envenomation's included but were not exclusive to bites from African cobras and vipers. The public capacity to handle envenomations from exotic, non-native venomous snake in Europe is limited in both the expertise to handle envenomations and having antivenin readily available. However, in spite of several cases of envenomations only very few casualties are recorded.

Conclusions and recommendations

We conclude that snakes are traded extensively across the African mainland, with particular emphasis on species endemic to Western and Eastern Africa that are harvested for the international pet trade. Several species of West African snakes recorded in this analysis i.e. *A. chlorechis*, *D. viridis*, *N. nigricollis* and *Bitis nasicornis*, indicate a targeted and persistent exploitation, questioning sustainability and therefore possible local declines. Geographically range-restricted species e.g., *A. ceratophora* and *A. nitschei* warrant significant monitoring due to continuous exploitation. One species, Ashe's bush viper (*Atheris desaixi*) that has a geographically localized distribution and has reflected an increase in collection pressure was listed in CITES Appendix II on 02/01/2017. Species found to be highly popular in this analysis and previous studies include; *A. squamigera*, *Bitis rhinoceros*, *B. nasicornis* and *B. gabonica*. Queries were only conducted in English, future studies should be conducted in Arabic and Asian languages aiming to record and monitor trade in African snakes destined for the Asian and Middle East pet market. Especially the Asian market is infamous for wildlife exploitation. More species assessed as Least Concern [LC] are exported from two of the main exporter hubs in Africa (Ghana and Egypt), compared to other countries e.g. Uganda, Tanzania, Cameroon, Ivory Coast, Niger, and Togo. Unfortunately of the 23 most frequently traded African non-CITES snakes 15 are classified as Not Evaluated. The lack of basic biological and ecological knowledge of these species and thereof Red List assessments could potentially shelter trade more detrimental than previously known.

We recommend that international trade in African snakes needs a thorough investigation to improve understanding of current threats and the conservation status of exploited species. Population surveys are required to understand the effects of excessive local and regional harvests. The identification of the Environmental Vulnerability Score (EVS) that includes basic life history traits and the species geographic distribution should be coupled with a measure for pressure for human exploitation following Johnson et al. (2015) and applied to African snake species in particular. This may further add valuable data to better evaluate threat/conservation status of non-assessed African snakes in the IUCN Red List, and those that have been categorized Data Deficient (DD).

Range states should use the information provided by this study and related studies to enforce and broaden their legislation to monitor all species exploited for the international trade. Simultaneously we highly recommend a legislative initiative for the European Union that is equivalent to the US Lacey Act, as the EU represents a major player in importing wildlife, including non-CITES listed African snake species. This new legislation would therefore also regulate trade in non-CITES, European Wildlife Trade Regulation species and particularly those that are nationally protected and endangered in their country of origin. Such initiative has already been introduced and recommended to the European Commission back in 2016 and indicated within the EU Action Plan against Wildlife Trafficking, stating, "The EU must explore the possibility of introducing legislation to prohibit the import, trade, and re-export of species that are protected in their countries of origin. The US Lacey Act is an example of such legislation. While CITES is a useful tool for regulating wildlife trade and protecting endangered species, it does not encompass all critical species, nor is it able to react to changing circumstances quickly enough and therefore provides criminals with easy opportunities to exploit loopholes"(European Commission 2016).

In order to tackle possible detrimental trade activity, reducing consumer demand for illegally sourced wild-caught individuals, or individuals from populations where basic ecological knowledge is limited must be made a top priority. We recommend the prioritization of public education on the collection and trade in wild specimens, as this has proven successful elsewhere (Moorhouse et al. 2017). Educational campaigns should target reptile keepers and include the following key conservation concepts: captive breeding, endemics, genetic diversity, welfare, and sustainable utilization. By addressing the consumer, we hope to shift demand towards transparent, ethical and sustainable supply chains throughout the pet reptile trade. Where possible, captive breeding, ranching and/or wild harvests should be promoted in source countries to improve in situ conservation initiatives in concert with rural development and livelihood improvement. However, in promoting these activities, it is essential to ensure proper regulation and monitoring protocols are in place from the outset to prevent potential laundering activities from undermining the objectives.

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