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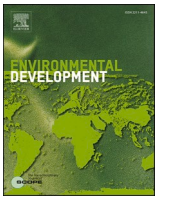

Global online trade in primates for pets

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ABSTRACT

The trade in primates as pets is a global enterprise and as access to the Internet has increased, so too has the trade of live primates online. While quantifying primate trade in physical markets is relatively straightforward, limited insights have been made into trade via the Internet. Here we followed a three-pronged approach to estimate the prevalence and ease of purchasing primates online in countries with different socioeconomic characteristics. We first conducted a literature review, in which we found that Malaysia, Thailand, the USA, Ukraine, South Africa, and Russia stood out in terms of the number of primate individuals being offered for sale as pets in the online trade. Then, we assessed the perceived ease of purchasing pet primates online in 77 countries, for which we found a positive relationship with the Internet Penetration Rate, total human population and Human Development Index, but not to Gross Domestic Product per capita or corruption levels of the countries. Using these results, we then predicted the levels of online primate trade in countries for which we did not have first-hand data. From this we created a global map of potential prevalence of primate trade online. Finally, we analysed price data of the two primate taxa most consistently offered for sale, marmosets and capuchins. We found that prices increased with the ease of purchasing primates online and the Gross Domestic Product per capita. This overview provides insight into the nature and intricacies of the online primate pet trade and advocates for increased trade regulation and monitoring in both primate range and non-range countries where trade has been substantially reported.

1. Introduction

Unregulated wildlife trade is a major threat to wildlife conservation worldwide (Cardoso et al., 2021; Shirey and Lamberti, 2011). One in every four wild animal species on the planet is currently exploited for trade, with tropical species particularly susceptible (Scheffers et al., 2019). Live individuals, body parts, and derivatives are traded for several purposes: decoration, medicinal use, food, and as pets (D'Cruze et al., 2021; El Bizri et al., 2020; Ingram et al., 2021; Phelps et al., 2010). Wildlife trade is a multi-billion-dollar sector, in which the legal trade in wildlife is thought to be worth more than US$ 400 billion (Nijman, 2021), while estimates of the yearly illegal trade in wildlife vary widely from US$ 4 to 23 billion ('t Sas Rolfes et al., 2019), i.e., roughly 1–5% the legal trade size. For live primates, the international trade, both legal and illegal, has been estimated at US$ 117 and US$ 138 million annually (Nijman, 2020; Norconck et al., 2020). When considering only the illegal trade in live primates, no formal monetary estimates are currently available, but if proportionally similar to the wider wildlife trade, we can approximate the economic value to be roughly US $1 to 7 million per year.

Sixty percent of primate species are threatened with extinction and almost 75% face population declines (Estrada et al., 2017). As such, domestic and international trade in live primates has been flagged as an urgent matter of concern for their conservation (Blair et al., 2017; Ceballos-Mago and Chivers, 2010; Duarte-Quiroga and Estrada, 2003; Estrada et al., 2018; LaFleur et al., 2019; Norconck et al., 2020; Mayor et al., 2022; Nijman et al., 2011; Scheffers et al., 2019). Historically, the live primate trade has involved large-scale companies that trade captive-bred or wild-caught primates internationally like other commodities, while small-scale traders offer live primates for sale in brick-and-mortar pet shops and markets, or as travelling traders. As Internet access has become increasingly widespread, this physical trading has shifted dramatically towards online markets (Bergin et al., 2018; Kitade and Naruse, 2020; Nijman et al., 2019; Siriwat and Nijman, 2020).

With the recent popularisation of e-commerce and increased access to the Internet, suppliers, and sellers have been provided with an unprecedented connection to potential new consumers and expanded markets, especially through social media sites (Nijman et al., 2019; Morcatty et al., 2021). In the EU, the number of people that ordered goods or services online in the previous 12 months increased from 54% in 2009 to 71% in 2019. This increase was markedly steeper for younger and higher educated groups (Anonymous, 2020). A similar pattern is seen in China (Hongfei, 2017), India (Goyal, 2015), South Africa (Goga et al., 2019), and Brazil (de Lima Enext, 2017). These trends have also been mirrored in the online trade of primates as pets, with younger generations more interested in having non-domesticated animals as pets than older generations (Cronin et al., 2022). In particular, social media has played a strong role in influencing consumer attitudes and increasing demand for wild animals as pets. For example, an analysis of posts containing galagos, also know as bush babies (Family Galagidae) (Nekaris, 2013), on Tiktok and Instagram showed that 95% of the comments

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indicated a desire in owning a galago. In a period in which post views of galagos increased by up to 472%, there was a correlated increase in google searches of the term "galago pet" and in the number of live galagos being exported (Svensson et al., 2022).

The ability to shop online is dependent on the Internet Penetration Rate (IPR), i.e., the percentage of the total population of a given country or region that uses the Internet, and this percentage varies widely. While in certain parts of the world, such as Scandinavia, the IPR is close to 100%, in regions such as West Africa or countries like Papua New Guinea and Madagascar it remains under 12% (Miniwatts Marketing Group, 2020). In addition, other socio-economic factors may influence the online trade of primates. For example, the Human Development Index (HDI) and Gross Domestic Product (GDP) have been reported to have a positive relationship with conservation outcomes (Ament et al., 2019; Barnes et al., 2016), while less corruption, and consequently more effective law enforcement, may increase the efficacy of punitive measures, increasing the socio-legal and financial costs of engaging in illegal activities (Cooney et al., 2017).

Despite the urgent need to understand the ever-increasing online primate trade from a global perspective, to date only limited individual studies have reported the sale of live primates over the Internet within a few specific countries and no comprehensive overview has been presented on this topic. Here, we review the online trade of live primates as reported in the literature, characterising the nature of these studies, the platforms used to advertise sales, and the number of individuals being offered for sale per country. Secondly, using knowledge from a large number of independent assessors, we provide an overview of the prevalence of online trade based on the relative ease of purchasing live primates online in 77 countries, and how this is linked to four country-level socioeconomic factors - IPR, GDP per capita, HDI and Corruption Perception Index (CPI). Based on the identified socioeconomic factors, we model the prevalence of live primate online trade at the global level. Thirdly, we assess correlates of asking prices by focussing on two primate taxa that we observed being sold in significant numbers and across various platforms in different countries, capuchins (Cebinae) and marmosets (Callitrichidae). Through dedicated searches and detailed statistical modelling, we present a quantitative overview of the prevalence of the online primate pet trade, and, importantly, we discuss how data from online sale postings can be used to provide insight into the nature and intricacies of the live primate pet trade.

2. Material and methods

2.1. Literature review

From June to November 2022, we used Google Scholar and the Web of Science to search for articles, reports, book chapters, and theses (in English, French, German, Dutch, Portuguese, Bahasa Indonesia, and Spanish) that reported on the trade in live primates for pets and filtered for those that included data on the online trade. We used the following keywords: *primate** and all major primate genera (e.g., *Macaca, Cebus, Nycticebus, etc.*) AND *online trade*. In addition, we consulted the Tess Lemmon Memorial Library of the Primate Society of Great Britain housed at Oxford Brookes University for reports that were not available online, and we queried all the co-authors for additional studies.

For each study, we extracted data on: i) whether or not the study was focussed exclusively on primates (either one or more species) or on a more diverse range of species, ii) the platform used by the sellers, iii) the number of primates that were observed for sale, and iv) the duration of the study (i.e., the length of time over which the online trade was monitored). For analysis, we only focused on those studies where at least five primate species were offered for sale in an individual country, as the likelihood of missing studies that reported a smaller number of primates (mostly as part of a larger more general wildlife trade study) was considered to be high.

2.2. Ease of purchasing pet primates online

From January to October 2020, we contacted members of the Oxford Wildlife Trade Research Group, alumni of the postgraduate programmes in primatology and primate conservation at Oxford Brookes University, and colleagues with a good working knowledge of the online trade in wildlife to assess the prevalence of online trade in primates as pets and the ease of purchase. Forty-five individuals agreed to assess one or more countries. Assessors only considered countries or territories with which they were familiar (either as country nationals or because of work, study, or research). Thirty-four countries were assessed by one assessor only, while forty-three countries were assessed independently by two or three assessors, so each received multiple assessments (see Supplementary Table S1).

Assessors conducted searches using a combination of general keywords for primates (such as monkey, ape, and marmoset) in local languages, along with the search terms "sale" or "trade". The online platforms searched were Facebook, Instagram, Baidu, WeiBo, Mercado libre, auction sites and classified ads in each country (see Supplementary Table S1). We only considered 'open' or 'public' groups/platforms or groups that could be joined by minimal effort (i.e., by making a single request to a central administrator, with no further restrictions/evaluations of access). We excluded groups that were secret and required an invitation or groups that required evaluation to join due to ethical considerations and the challenge of standardising collection in different countries.

Searches were done in one or more of the country's national languages, in addition to English when appropriate. Overall, searches were conducted in 30 languages, with English (20 countries), Spanish (10), Arabic (12), French (6), and Portuguese, Dutch/Afrikaans and Bahasa Indonesia/Malay/Malaysia/Jawa (4 countries each) being the most common. The other languages included: Bosnian, Burmese, Cambodian, Chinese, Croatian, Danish, German, Greek, Hindi, Italian, Japanese, Korean, Laotian, Nepali, Russian, Serbian, Slovenian, Philipino, Swedish, Thai and Vietnamese.

Assessors were then asked to rate the ease of finding live primates in online trade using an eight-point Likert scale, based on what could be found online by searching relevant local platforms in a single afternoon (6 h):

- The zero in the scale should be selected when no trade was found at all.
- If primate trade was detected, a value from 1 to 7 should be selected according to the agreement level to at least one of the follow sentences: "i) primates were easily available; ii) primates were available on multiple trade platforms or offered by multiple vendors; iii) multiple species were sold; iv) a substantial number of individuals were offered for sale". Each assessor assigned a score to each of these aspects, and the average of these values was used to generate an overall score rounded to the nearest point (up or below). The agreement level from 1 to 7 represents Strongly Disagree, Disagree, Slightly Disagree, Neither Agree nor Disagree, Slightly Agree, Agree and Strongly Agree (Likert, 1932). We deemed these 'online trade scores' to represent the prevalence of online primate trade and consequently the ease of purchasing pet primates online.

To check for the level of agreement between different assessors, we compared the online trade score given by the two first assessors for the same country using a Pearson's correlation. We found a high degree of agreement (Pearson's $R = 0.89$, $t = 12.9$, $df = 47$, $P < 0.0001$) (see Supplementary Fig. S1). This provided confidence in the accuracy of our assessors, and we therefore included in our analyses the additional 34 countries for which we only had one assessment for further analysis and the scores for countries with multiple assessments were averaged.

We then investigated the potential relationship between the online trade scores in all countries assessed with the following five socio-economic and ecological variables:

(1) Country GDP per capita (as of 2019) in US$ as a reflection of purchasing power, obtained from the World Development Indicators (World Bank, 2019).
(2) IPR (as of 2020) identifying what percentage of the population uses the Internet, obtained from Internet World Stats (Miniwatts Marketing Group, 2020).
(3) HDI (as of 2019) on a scale of 0–1 (range: 0.377–0.954), which takes into account life expectancy at birth, expected years of schooling for children, mean years of schooling for adults, and GDP per capita (UNDP, 2019).
(4) CPI (as of 2019), on a scale of 0 (very corrupt) to 100 (very clean), which reflects perceived levels of public sector corruption by expert assessments and opinion surveys. Published annually by Transparency International (Transparency International, 2019).
(5) Human population size by country (as of 2020) obtained from the World Development Indicators (World Bank, 2020).
(6) Primate species richness per country taken from Estrada et al. (2017). Non-primate range countries received a richness of 0, except for in the cases of well-established populations of introduced primates, such as green monkey *Chlorocebus sabaeus* on the Cape Verde Islands and Barbados (Boulton et al., 1996; Hazevoet and Masseti, 2011).

Whether or not asking prices were included in online ads varied widely between countries. Often the only way to obtain prices was to contact the trader directly, which we did not do. During the search, we observed that marmosets and capuchins were the only species offered for sale that repeatedly appeared in almost all countries assessed. Therefore, for these two commonly traded primate taxa we collected data on asking prices displayed, corrected by inflation as of November 2020 and converted to US dollars. We then used these two species as indicators to understand possible price fluctuations for the other traded species. We excluded unusually low starting prices ('0' or '1') and prices that were clearly only added to meet the requirements of the online platform (e.g., '1234'). For this study, there was no interaction with the traders and no data were permanently stored.

2.3. Data analysis

To assess the relationship between the online trade scores and the five socio-economic and ecological variables above, we ran a Generalized Additive Model for Location, Scale, and Shape (GAMLSS) (Stasinopoulos and Rigby, 2007). An advantage of using GAMLSS instead of a Generalized Linear Model is that the '*gamlss*' R-package provides distribution families that balance the frequency of 0's in the count data (such as the zero-adjusted gamma). We tested for multicollinearity among independent variables with a pair-wise correlation test and found IPR, GDP, HDI, and the CPI were collinear (Pearson's $R > 0.6$), and therefore they were not included concomitantly in the same model. We used the IPR as our baseline and *a posteriori* re-ran the selected model with the other collinear variables to obtain the relationship and statistical values for all variables.

To account for the potential of non-linear effects, we tested these using a penalized cubic splines function (cs). In order to avoid overfit, a non-linear model was only chosen over a linear one if the improvement in fit was deemed significant enough to justify the incurred penalty. To assess the drivers of marmoset and capuchin sales prices we ran a GAMLSS which tested whether sales prices were affected by the online trade score (ranging from 0 to 7), GDP, whether or not it was a primate-range country, and/or the primate taxa (marmosets vs capuchins). Model selection was conducted based on the Akaike Information Criterion (AIC), with the model displaying the smallest AIC selected for each research question. If a more complex model demonstrated a lower AIC than the baseline model (with a sufficiently large difference from the second-best model – i.e., a difference of more than 2 is considered significant), we considered this as an indication of significant improvement over the simpler model. All ΔAIC values exceeded the threshold of 2, relative to the second-best model and to the null model (i.e., devoid of predictor variables) and are presented in the results (Burnham and Anderson, 2004).

Since we did not have assessors for all countries in the world, we tested whether the subset of countries we assessed were globally representative by comparison to global averages. For that, we conducted separate one-sample t-test to compare each variable (IPR, GDP, HDI, and CPI) in our sample against the global average. We used Shapiro–Wilk's test to test normality and Levene's test for homogeneity of variances, considering the assumptions for Pearson's correlation and T-test.

Based on our best-fit model and the variables selected as the main predictors of the online trade score (namely IPR and human population size), we used the function *gamlss.predict* to predict the online trade score for all non-assessed countries (N = 94). Countries that did not have information available for the selected predictor variables were excluded from the prediction (Greenland, North Korea, South Sudan, Somalia, Western Sahara and Eswatini).

For all statistical analyses, we used R 3.6.3 software (http://www.R-project.org/). We used the R-packages *gamlss* (Version 5.1–6) for the GAMLSS and the prediction and *vegan* (Version 2.5–6) for Pearson correlation, one sample T-Test, homoscedasticity test and normality test. We assumed significance when $p < 0.05$. We used Quantum GIS 2.18.9 (https://quantum-gis.en.softonic.com/) to create the map with the online primate trade score predictions.

2.4. Ethical considerations

Traditionally, researchers interested in the live primate trade have visited pet shops, wholesale traders (exporters), or brick-and-mortar animal markets (e.g., D'Cruze et al., 2021; Duarte-Quiroga and Estrada, 2003; Nijman et al., 2017; Shepherd, 2010). Where trade happens openly, all involved have a reasonable expectation that they can be observed by others, just like when visiting any other public space (Burkell et al., 2014; Siriwat et al., 2019). A small percentage of trade does occur out of sight, in back alleys, or at traders' premises, and can only be observed when one is accepted as part of the group. The online trade that has emerged in recent years is not all that different from the trade in open, public spaces. It is in the best interest of the sellers to ensure that potential customers have the opportunity to see and buy whatever they have on offer. While a proportion of wildlife trade occurs out of sight, in the "back alleys of the Internet", or even on the hidden or 'dark' web, that proportion is small (Harrison et al., 2016; Stringham et al., 2023). While the online trade in primates as pets mostly occurs in the open, in some countries, one has to request access to private online groups. As noted by Siriwat et al. (2019), joining these groups often merely involves sending a request after which access will be granted within a 24-h period.

Due to the potentially sensitive content, we used guidelines from Roulet et al. (2017) for covert observations and the recommendations of Kosinski et al. (2015) for online research. The assessment of the online trade in primates was conducted without direct interaction with any of the vendors, group members, or administrators (other than when requesting membership).

Although the majority of our data were available in the public domain, some groups required access requests. In these instances, covert observation was deemed justifiable as it was necessary to obtain accurate estimates of trade and to ensure the quality of data collected. All data was collected manually and no webscraping or application programming interfaces (APIs) were used. The data collected was minimized where possible, no personal data were collected, and no data were permanently stored. We anonymized data after collection, and we do not publish any information that may be attributed to any one individual or group (buyer or seller). Since the data used for this specific study were available in the public domain, no research ethics permission was needed. This study did not include any direct research on animal or human subjects. The authors declare that they have no conflicts of interest.

3. Results

3.1. Overview of studies on the online trade in live primates

We identified 20 studies that reported on the online sale of primates from a total of 24 countries; 12 focused on primates, often specific taxa, and eight focused on a wide range of wildlife, including primates (Table 1). In 14 of the 24 countries, fewer than 100 individual primates were found offered for sale, but it was often unclear from the methodology how frequently online platforms were checked (i.e., daily, weekly, irregular) or how many platforms were monitored. Countries where a relatively large number of pet primates were offered for sale were the USA, Malaysia, Thailand, South Africa, Ukraine and Russia. Auction sites and Facebook were the most popular platforms to monitor, and presumably purchase, primates. In Indonesia and Turkey, Instagram was a popular platform for trading primates as pets. The UK was the only country for which we could find multiple studies covering over a decade. In most cases, the studies involved at least several months of sampled data or monitoring, but only six covered a period of one year or more.

3.2. Global assessment of the ease of online purchasing of primates

We obtained 130 online trade scores from 45 assessors for 77 countries during a single day of investigation per country, including 38 primate range countries. When compared to the averages of socio-economic factors for 171 countries for which data were available, our sample countries had a slightly higher IPR (54.9 ± SD 28.2 vs 46.8 ± SD 29.5: t-value = 2.5, df = 74, $P = 0.02$), a higher HDI (0.761 ± SD 0.135 vs 0.716 ± SD 0.155; t-value = 2.9, df = 75, $P = 0.005$), but a similar GDP per capita (US$ 27,780 ± SD 26,419 vs US$ 22,181 ± SD 22,207: t-value = 1.9, df = 75, $P = 0.1$), and similar levels of corruption (80.4 ± SD 50.8 vs 88.3 ± SD 51.1; t-value = −1.4, df = 74, $P = 0.18$). Therefore, while our sample was slightly biased towards countries with higher levels of Internet access and human development, we believe that this database is still globally representative.

Facebook, Instagram, and online pet shops were the most common platforms where primates were available for sale. The overall online trade score differed little between primate range countries (mean of 2.56 ± SD 2.01) and non-range countries (mean of 1.98 ± SD 1.88). We found a positive relationship between the trade score and the IPR, HDI, and the country's human population (Table 2; Fig. 1). We did not find relationships between the online trade score and either the CPI, GDP per capita, primate richness or between range and non-range countries.

Table 1
Previous research concerning the online trade in live primates. Only studies in which at least five primates were offered for sale were included. Primate range countries are italicized. *These numbers may include primates that are not alive. ** these number included previous months in which advertisements were consult (not only the month of social media use); considering that some ads may be deleted over time, this value may underestimate the total number of individuals to be recorded.

Country/region	Species	Legality of keeping primates as pets	Platform	Length of monitoring	Number of individuals recorded	Reference
Asia						
India	Slow and slender lorises	All slow and slender lorises are protected	RicePuller	10 months	86	Morgan and Nijman (2020)
Nepal	Bengal slow lorises	Bengal slow loris is protected	RicePuller	10 months	8	Morgan and Nijman (2020)
Thailand	Wide range of wildlife	Primates are protected; captive-bred primates can be traded	Facebook	1 month	198	Phassaraudomsak and Krishnasamy (2018)
Thailand	Primates and carnivores	Primates are protected; captive-bred primates can be traded	Facebook	18 months	380	Siriwat et al. (2019)
Indonesia	Apes	All protected	Instagram, Facebook	32 months**	127	Nijman et al. (2021)
Malaysia	Gibbons	All gibbons are protected	Instagram, Facebook	13 months	5	Smith (2018)
Malaysia	Wide range of wildlife	Most primates are protected	Facebook	5 months	27	Krishnasamy and Stoner (2016)
Malaysia	All primates	Most primates are protected	Facebook	10 months	736	Zainol et al. (2018)
Turkey	Slow lorises	Unknown	Instagram	11 months	135	Kitson and Nekaris (2017)
United Arab Emirates	Wide range of wildlife	Unknown	Auction sites	6 weeks	8	IFAW (2014)
Japan	Slow lorises	Some species can be kept as pets	Online pet shops	3 months	56	Musing et al. (2015)
Africa						
Algeria	Barbary macaque	Barbary macaques are protected	Classified ads	6 months	7	Bergin et al. (2018)
South Africa	Mammals	Legal	Facebook, South African advertising websites	12 months	115	Shivambu et al. (2021)
Cameroon, Chad, DRC, Gabon, and Nigeria	Wide range of wildlife	Some species protected – license required/Some species protected/Unknown/All protected/License required	Classified/listings, E-commerce, Forum Online marketplace	39 months	80*	Woolloff et al., (2022)
Europe						
UK	All primates	Certain primates can be traded	Classified ads	4 days	40	Soulsbury et al. (2009)
UK	All primates	Certain primates can be traded	Classified ads	–	146	Travers and Turner (2005)
UK	All primates	Certain primates can be traded	Specialists' website	1 day	44	Anonymous (2012)
UK	Wide range of wildlife	Certain primates can be traded	Auction sites	6 weeks	6*	IFAW (2008)
Germany	Wide range of wildlife	Primates cannot be kept as pets	Auction sites	6 weeks	7*	IFAW (2008)
Poland	Wide range of wildlife	Certain primates can be kept as pets	Auction sites	6 weeks	27	IFAW (2014)
Russia	Wide range of wildlife	Unknown	Classified ads, online pet shops	3 months	>128	Krever and Ivannikova (2020)
Russia	Wide range of wildlife	Unknown	Auction sites	6 weeks	117	IFAW (2014)
Ukraine	Wide range of wildlife	Unknown	Auction sites	6 weeks	219	IFAW (2014)
America						
USA	Primates	Some primates can be traded in certain States	Specialists' websites	12 months	551	Seaboch and Cahoon (2021)
USA	Wide range of wildlife	Some primates can be traded in certain States	Auction sites	6 weeks	18*	IFAW (2008)
Canada	Wide range of wildlife	Certain primates can be kept as pets in some provinces	Auction sites	6 weeks	6*	IFAW (2008)
Colombia	Wide range of wildlife	Unknown	Auction sites	6 weeks	28*	IFAW (2008)
Brazil	Wide range of wildlife	Certain primates can be traded only by certified breeder under a quota	Facebook, WhatsApp	4 months	>81	Wyatt et al. (2022)

Table 2
Details on the Generalized Additive Model for Location, Scale and Shape (GAMLSS) of the drivers of primate online trade scores and drivers of prices of marmosets and capuchins sold.

Response variable	Predictor variables	Estimate	Std. Error	t-value	*P* value	ΔAIC (ΔAIC_{null})[c]
Online Trade Score[a]	(Intercept)	−0.022	0.245	−0.9	0.920	3.20 (12.03)
	Internet penetration rate	0.008	0.004	2.7	0.009*	
	Human development index	1.815	0.745	2.4	0.017*	
	Human population	0.172	0.044	3.9	0.001*	
	Corruption perception index	−0.004	0.004	0.8	0.40	
	GDP per capita	0.001	0.003	−0.1	0.89	
	Primate richness	−0.001	0.004	−0.3	0.76	
	Range/non-range country[d]	−0.013	0.231	−0.1	0.96	
Asking price[b]	(Intercept)	3.170	0.529	6.0	<0.001*	4.31 (38.21)
	Online Trade Score	0.691	0.093	7.5	<0.001*	
	GDP per capita	0.040	0.007	6.0	<0.001*	
	Range/non-range[d]	−0.516	0.304	−1.7	0.097	
	Primate species[d]	−0.591	0.300	−2.0	0.055	

*$p < 0.05$.
[a] Zero-adjusted Gamma distribution (link function log).
[b] Gamma distribution (link function log).
[c] ΔAIC is the difference between the AIC of the best model and the second-best ranked model and ΔAICnull is the difference between the AIC of the selected model and the AIC of the null model.
[d] Reference classes: Non-range countries and capuchin.

We then predicted the online trade scores for countries we could not directly assess with modelling while accounting for its IPR, and human population, to provide a global picture of the prevalence of online primate trade. We found that USA, South Africa, Russia, and Southeast Asia (Indonesia, Malaysia, Vietnam and Thailand) stand out as the hotspots for the ease of online purchase of primates, followed by some South American and European countries (see Table 3). Online trade of live primates was minimal in most of continental Africa and South Asia (Fig. 2).

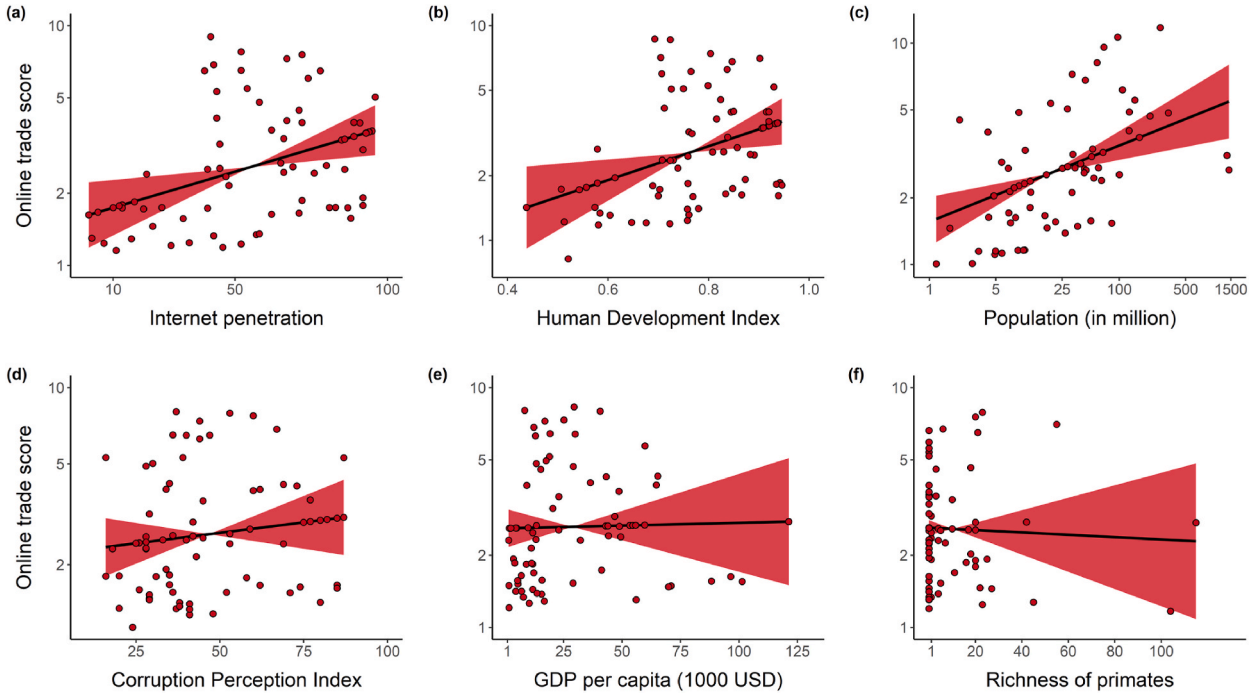

Fig. 1. Relationship between the online primate trade score and (a) the Internet Penetration Rate, (b) Human Development Index, (c) human population, (d) Corruption Perception Index, (e) GDP per capita and (f) primate species richness. Points are normalized partial residuals. Y-axis is plotted as original values at a log (ln) scale. The shaded area represents the 95% confidence interval. Only relationships (a), (b) and (c) are significant (see Table 2 for details).

3.3. Price of primates traded online

The primates most frequently recorded in trade were capuchins, marmosets, squirrel monkeys (genus *Saimiri*), tamarins (*Saguinus*), slow loris (*Nycticebus, Xanthonycticebus*), macaques (*Macaca*); with capuchins and marmosets the groups that appeared most consistently across a large range of countries. The mean price for a capuchin (mean US$ 2957 ± SD 4900) or a marmoset (mean US$ 1859 ± SD 2181) differed greatly between countries. At the country level, this price was positively correlated with both the ease of purchasing primates online and GDP per capita (Table 2; Fig. 3). Although not statistically significant, asking prices for capuchins tended to be higher than that for marmosets ($p = 0.055$), and these two primate taxa tended to cost more in non-primate-range countries than in primate-range countries ($p = 0.097$) (Fig. 3).

Table 3
Assessed countries deemed by at all independent assessors to have a high online presence of the live primate pet trade (scores 6 or 7 on a 0 to 7 scale), with respective country-level characteristics. See Methods for variable definitions.

Country	Internet penetration rate (%) (2020)	GDP per capita	Human Development Index	Corruption Perception Index	Online Trade Score mean ± SD	Most commonly traded primates
Indonesia	63*	12,302	0.707	40	7.0 ± 0.0	Macaques, slow lorises
Russia	71	29,181	0.824	28	6.5 ± 0.7	Lemurs, slow lorises
USA	96	65,281	0.920	69	6.5 ± 1.0	Marmosets, capuchins
Malaysia	81	29,228	0.804	53	6.0 ± 0.0	Slow lorises
Thailand	82	19,228	0.765	36	6.0 ± 0.0	Slow lorises, marmosets
South Africa	55	12,999	0.705	44	6.0 ± 0.0	Marmosets, capuchins
Japan	94	43,236	0.915	73	6.0 ± 1.0	Marmosets, squirrel monkeys

* Internet penetration rate is higher in the western part of Indonesia (Sumatra, Java, Bali), where primates are native, compared to eastern Indonesia (Moluccas, Papua), where primates are not native.

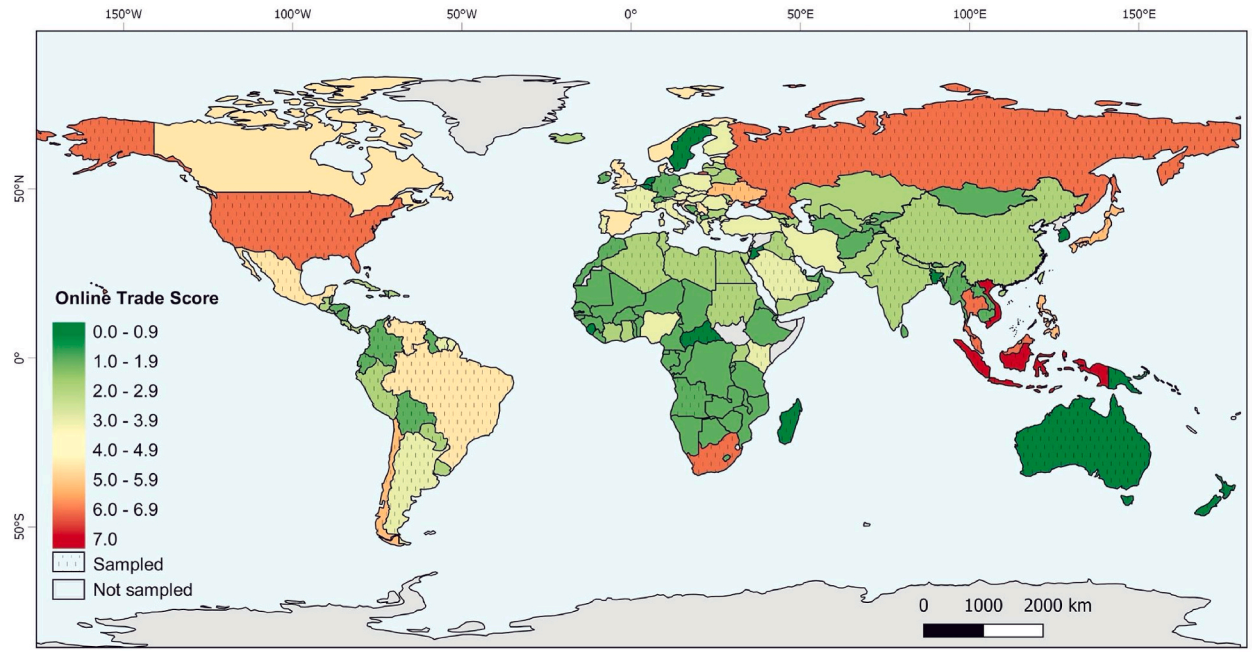

Fig. 2. Online trade scores representing the prevalence of online primate trade (0 - no trade present at all; 7 - easily available, multiple platforms, multiple vendors, multiple species, a substantial number of individual primates offered for sale) accounting for the Internet Penetration Rate and human population size. Dashed countries represent the 77 countries scored by independent assessors and countries with no dashes represent those with scores predicted through modelling. Countries or territories in grey were excluded from the prediction due to the absence of data (see Supplementary Table S1 for details).

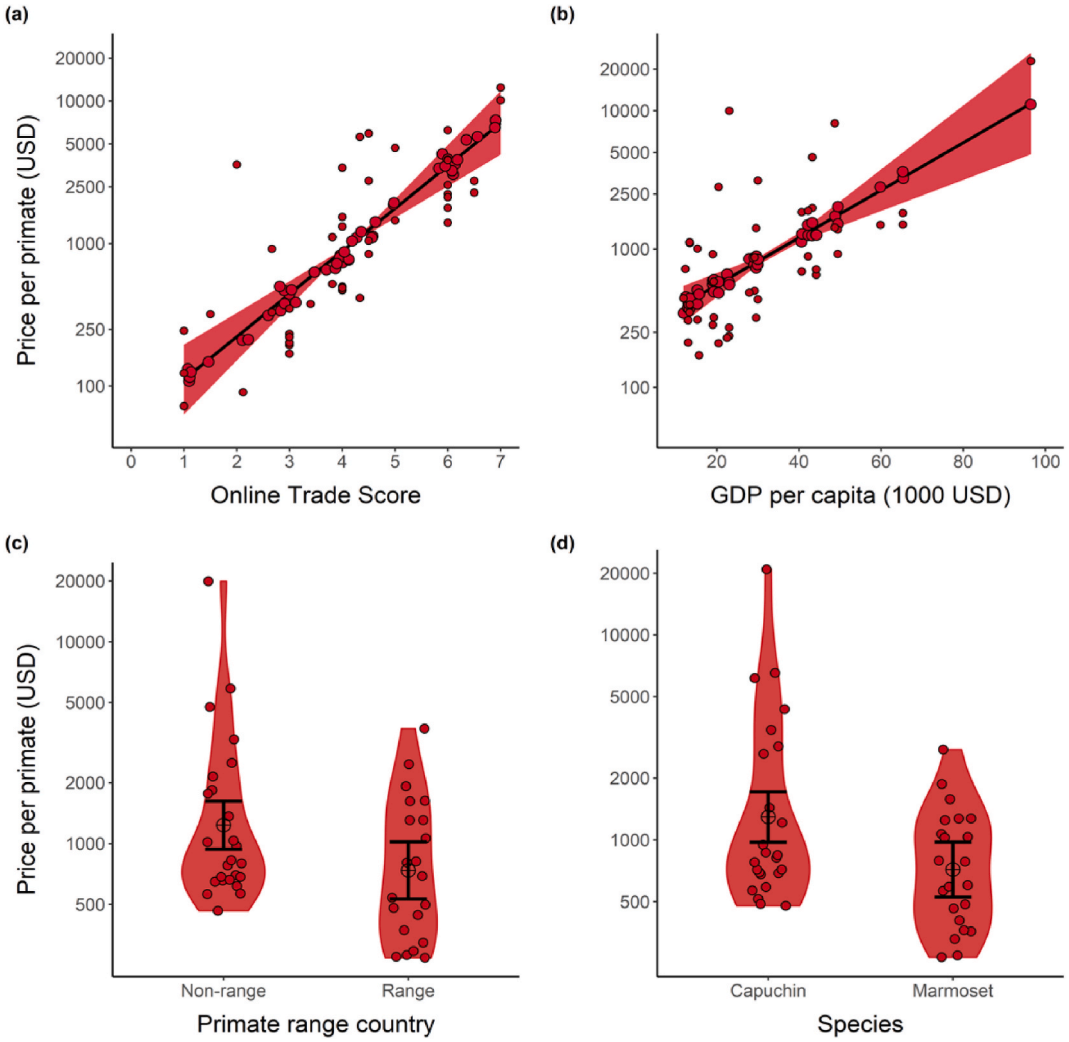

Fig. 3. Relationship between the asking price of an individual marmoset and capuchin (in US$) and (a) the online trade score (ranging from 0 to 7) and (b) GDP per capita of the country in which these were offered for sale; and difference of asking prices between (c) primate-range countries and non-primate-range countries; and (d) primate taxa. Only relationships (a) and (b) are statistically significant (see Table 2 for details). The shaded area represents the 95% confidence interval.

4. Discussion

4.1. An overview of the online trade in primates

Our results indicate that the practice of selling live primates online is widespread across both range and non-range countries; however, published research specifically addressing this issue is limited at present. Primate specific studies of online trade thus far have often been restricted to specific taxa (Table 1) and appear to have a bias towards Asia (Musing et al., 2015; Phassaraudomsak and Krishnasamy, 2018; Siriwat et al., 2019; Zainol et al., 2018; Nijman et al., 2021). Comparing the results from these studies and extrapolating to a wider range of taxa or regions is hampered by varying methodology and lack of detail in written methods. In the literature consulted, when methodology was discussed, there was significant variation in the strength of efforts to assess the online primate trade, from single-instance website checks to long-term, consistent monitoring.

Our assessment of the prevalence of the online trade and the ease to which live primates can be purchased online illustrates that primates are kept as pets in a large number of sampled countries and allowed us to extrapolate with statistical modelling to the rest of the globe. In our model, South and North America, Europe, and Southeast Asia are identified as areas where primates are easily purchased online, albeit with marked differences between individual countries. Continental Africa (sans South Africa) and South Asia stand out as regions with relatively low levels of online trade in pet primates (scores 0 and 1). Primates are commonly kept as pets and traded in physical markets in these regions, so this result may reflect the generally low levels of Internet penetration (Nekaris and Bergin, 2017; Casanova and Sousa, 2007). We highlight that in these regions, the knowledge of local communities in sourcing, selling,

and purchasing primates for the pet trade plays a more important role here than communicating via the Internet (Ceballos-Mago and Chivers, 2010; Norconck et al., 2020; Račevska et al., 2020; Reuter and Schaefer, 2016).

Our research reveals a significant, positive relationship between HDI and online trade score, with the highest effect size among the variables tested. Generally, higher levels of HDI are associated with greater health and education standards and higher gross national income per capita, which are typical indicators of developed countries. This finding contradicts the initial expectation that a lower HDI, which correlates with weaker conservation efforts and surveillance, would result in increased levels of primate trade (Estrada et al., 2020). Our results align with the findings of (Bachmann et al., 2022) who examined the Africa-Europe South-North gradient of wildlife hunting, demonstrating that hunting for entertainment purposes also increases as HDI rises. People with higher standard of living have more disposable income to spend on luxury items such as pets, and exotic pets are often seen as a status symbol (Spee et al., 2019). This relationship suggests that the primary driver behind the global online trade may be the demand for primates as pets in developed countries (often non-range countries for primates), driven by the desire for entertainment or status, rather than the prevalence of supply in countries where poverty leads to an inevitable exploitation of wildlife. These findings have important implications for conservation efforts, as by acknowledging this trend and implementing targeted interventions, it is possible to work towards reducing the demand for primates as pets in developed countries.

We did not find a statistical correlation between the online trade score and affluence, and while GDP is taken into account in the HDI, this suggests that merely GDP alone does not account for the variation observed. This may be because in our study we did not distinguish between the legal and illegal trade (see section 4.3). Previous research has shown that low GDP tends to be associated with illegal trade, while higher GDP is more likely to be associated with legal trade (Estrada, 2009; Morcatty et al., 2020). Therefore, further investigations that clearly distinguish the legality status of the animals sold are necessary to unveil whether, and how, GDP influence the online trade of primates.

All countries with an IPR below 50%, such as Sierra Leone, Myanmar, Bangladesh and Madagascar, had scored low on the level of online primate trade but once the IPR was above 50%, scores 5 and above were found frequently (Fig. 1). This suggests that there may exist a minimum threshold of Internet access needed at the country level before a shift in trade can occur from traditional brick-and-mortar markets to online platforms (cf. Nijman et al., 2019). A clear caveat to this, however, is that IPR is a country-level statistic and certainly within some countries there are marked differences in access to the Internet across geographic regions. For instance, Indonesia as a whole has an IPR of 63%, but that average is lowered because of very rural or less developed islands, while in urban areas of the island of Java, where over half of the population of Indonesia resides, the IPR can be higher than 70%. We expect a similar pattern in countries like Tanzania, Egypt, or Pakistan, where the overall country-wide level of Internet access is still limited, but there are large urban cities (i.e., Dar-el-Salaam, Cairo/Alexandria, and Karachi/Lahore) where Internet access is more universal, and e-commerce is much better established.

In addition to varying levels of Internet access within countries, while the assessed online trade scores represented the entire country, we acknowledge that certain countries have large variation in prevalence of online pet primate trade across geographic regions as well. For example, in China, primate trade in general appears more prevalent in the south than in the north and east (Ni et al., 2018), and we expect that this pattern is reflected in the online primate trade as well. In Thailand, trade in primates (and carnivores) was concentrated in the capital of Bangkok and the far southern provinces, close to the Malaysian border (Siriwat et al., 2019).

4.2. *Online international trade*

While the focus of this study was on domestic trade in pet primates, it is clear that this trade has at least two important international components. Firstly, while captive breeding for pets exists, we cannot discount the likelihood of international trafficking occurring before animals are posted online in non-range countries. Secondly, prospective buyers may have the option to order pet primates online from sellers based in nearby countries, allowing for post-sale international trade.

We found no difference between the ease of purchasing a pet primate in primate range countries compared to non-range countries and no correlation to the number of native primate species in the country, which contradicts previous findings from research on primate trade in physical markets (e.g., Svensson et al., 2021). Some of the countries that had a very high online trade score, i.e., where various primate species are almost universally available online, were non-range countries such as the USA and Russia. Additionally, in certain primate-range countries such as Japan and South Africa, the majority of primates offered for sale online were Neotropical primates, mainly capuchins, marmosets and squirrel monkeys. Those species had previously been recorded widely offered for sale in many countries (de Souza Fialho et al., 2016; do Nascimento et al., 2013). Slow lorises were not only prevalent in range countries such as Indonesia or Malaysia but were also commonly recorded in Japan and Russia (cf. Musing et al., 2015; Nekaris et al., 2013). This then suggests significant movement of primates from range countries to non-range countries, and, in certain countries, the establishment of commercial breeding of non-native primates to meet the demand for the domestic pet trade (e.g., Norconk et al., 2023).

One aspect that was flagged by several assessors was the ease of ordering pet primates online with the vendors from neighbouring countries; for example, a prospective pet owner in Singapore would be able to do an online search for vendors based in the Malaysian State of Johor immediately north of Singapore or the Indonesian province of Riau, just to the south. With a frequent flow of goods between these regions, delivery of a pet primate was not seen as problematic. Additionally, prospective buyers in Cyprus, a country that is part of the EU, could order primates online from Turkey through Northern Cyprus. Northern Cyprus is recognised as a nation only by Turkey and due to its strong political and economic ties to that country, this provides Cypriot buyers access to species purportedly brought in from Turkey, such as slow lorises and marmosets. Within the EU and also the Mercosur (the Southern Common Market, a South American trade bloc established in 1991), border inspections are limited and considerable differences in legislation

with regards to keeping primates as pets allow for virtual cross-border shopping in neighbouring countries (Svensson et al., 2023). As such, the ease of purchasing primates online is dependent in part on the socio-political situation in these countries and does not provide a complete picture of the ability of purchasing them.

We consider in this study open or public groups/platforms or closed groups that could be joined by minimal effort, based on the assumption that these types of groups would be more accessible and representative of the overall landscape of online wildlife trade. The trade in highly selective or secret groups or platform still occurs, particularly in regions with more stringent enforcement measures, and it may not have been captured by our trade score index. While this is true only for the illegal trade, and we cover legal and illegal trade, we acknowledge that our results of higher trade score index may be biased towards regions with less policing.

Asking prices of pet primates that are offered for sale online differ substantially, ranging from less than US$100 to over US$10,000. This is probably related to age, with younger ones usually more expensive than older individuals, in addition to species, country of sale, origin (captive-bred or wild-caught), and legality. While it may be legal to keep and trade primates as pets in many countries, there are serious risks attached to this trade as attested by the successful establishment of feral primate populations outside their native ranges (e.g. mona monkeys *Cercopithecus mona* in Grenada: Gunst et al., 2016; squirrel monkeys, vervets *Chlorocebus pygerythrus* and rhesus macaques *Macaca mulatta* in Florida: Anderson et al., 2017; rhesus macaques and patas monkeys *Erythrocebus patas* in Puerto Rico: González-Martínez, 2004; green monkeys *Chlorocebus sabaeus* on the Cape Verde Islands: Hazevoet and Masseti, 2011). Many non-native primates are readily available on the Internet in a wide range of countries, increasing the likelihood of the introduction of primates to new locations.

Greater contact with non-human primates, both within and outside of primate range countries, has the potential to facilitate the transfer of pathogens and diseases from primates to humans (de Souza Jesus et al., 2022; Morcatty et al., 2022a). This is evidenced by the monkeypox virus (Smith et al., 2009), herpes B virus (Huff and Barry, 2003), simian T-cell lymphotropic virus (Schillaci et al., 2005), simian foamy virus (Engel et al., 2006) and the general spread of diseases that are linked to the global trade in wildlife (Karesh et al., 2005; Pavlin et al., 2009). While these transmissions were from primate to human, the reverse has also been observed when a pet common marmoset was infected with human herpesvirus 1 and died as a consequence of it (Huemer et al., 2002). Physical trauma due to bites and scratches by pet primates is another cause of concern when there is an increase in the number of primates that are being kept as pets (e.g., Leung et al., 2015; Mease and Baker, 2012).

4.3. Legality of the online trade in primates

The issue of primate trade legality in the countries we assessed is a complex matter, without a clear-cut answer, as illustrated in Table 1 of the literature review. For example, in Brazil, while all wild primate species are protected and cannot be traded, there exists a legal trade in captive-bred primates of a limited number of species and individuals under a permit system. Therefore, online primate trade can be legal, as long as the seller has the required permits, and the animals are genuinely captive-bred. In contrast, Indonesia does not protect all wild primate species, but commercial trade in wild-caught primates is regulated through a quota system. However, for numerous species, these quotas have been set to zero for at least a decade, making a substantial part of the commercial trade in both protected and unprotected species illegal. In countries like the Netherlands, Singapore, Australia, and New Zealand primates cannot be kept as pets, all trade in primates for pets is illegal and these regulations are generally well-enforced.

In many other countries, while the majority of primate species are restricted, some exceptions are permitted for smaller species, such as marmosets and capuchins, which can be kept by private individuals as pets. In certain states in the USA, i.e., Alabama, Kansas, Nevada, West Virginia, there are virtually no restrictions on the keeping of any primate as pets and indeed as many as 100 chimpanzees *Pan troglodytes* are kept as a pet in private hands in these parts of the USA (Rainer et al., 2014). In other states, i.e., Louisiana, Minnesota, Maryland, there are restrictions in place that preclude private individuals from keeping all species of primate as pets. In Denmark it is legal to keep tamarins and marmosets as pets; in the UK all smaller primates, up to the size of a capuchin or a ring-tailed lemur *Lemur catta*, can be legally kept as pets, whereas in Chile, despite the high trade score achieved in this study, all primate species are prohibited to be kept as pets. In Thailand, all primates native to the country are protected and cannot be traded legally, but exotic primates can, provided their import into the country is compliant with CITES legislation or are captive-bred in Thailand (Siriwat et al., 2019).

In countries where regulatory frameworks are based on specific criteria, determining whether each primate advertised online represents legal or illegal trade is challenging. In addition, it is important to note that the issue of wildlife trade is not solely related to illegality. Legal trade can also be unsustainable, leading to negative impacts on biodiversity and ecological systems. As such, there is a need to ponder the concepts of legality, threat, and sustainability in order to better understand the intricate issues at play (Hughes et al., 2023). A more detailed and comprehensive study would be necessary to ascertain the legality of primate trade in such countries.

4.4. Recommendations to improve regulation of the online sale of primates as pets

A clear recommendation from our study is to commence a discussion on the need for increased regulation of trade in primates within many of the primate range countries, and indeed of several non-primate range countries, largely due to increased Internet-based sales. At the national level, environmental and governing bodies are urged to better enforce existing species-protection laws and legal frameworks to monitor and manage the rising sale of non-native species. Primates are excellent flagship species to anchor this debate (Chapman et al., 2020). Our results also show that the issue of online trade in live primates is international and will require multilateral coordination and intervention (Fukushima et al., 2021). We identified an unbalanced effort among studies already published, and a lack of in-depth information for several countries. Therefore, an increase in collaborative research and, more importantly, the

establishment of a common protocol to assess the traded species is required to facilitate coordinated decision-making efforts.

Many endangered primate species are explicitly and openly advertised for sale on websites appealing to buyers in multiple countries. Pet traders increasingly resort to the Internet in a wide range of countries. Improved packaging and infrastructure allow live primates to be ordered on the Internet and shipped to one's door in a matter of days. Especially for some of the smaller primate species (e.g. slow lorises) rising trade demands, including via the Internet, have seen an increase in wild-animal harvesting leading to their near extinction in various parts of Asia (Thach et al., 2018; Nekaris et al., 2010), similar to what has happened to Barbary macaques *Macaca sylvanus* (Van Lavieren et al., 2016). Although we could not always identify individuals to the species level, some taxa, such as the genus *Sapajus,* include Critically Endangered or Endangered species (such as buff-headed capuchin *S. xanthosternos* and crested capuchin *S. robustus*, respectively) which inhabit areas where trade was recorded or neighbouring regions. The Critically Endangered buff-headed capuchin may constitute a significant proportion of the illegal pet trade; for instance, it represents an alarming 54.8% of the total number of capuchin monkeys illegally held as pets in Brazil's Bahia state, as documented by do Nascimento et al. (2013). Although other taxa, such as marmosets may not be currently classified as threatened, the combination of trade with other existing anthropogenic threats, such as habitat loss and invasive species introduction, may pose a significant risk and condemn these species to population declines in the near future.

Alongside better assessments, improved legislation and law enforcement, the social media component in this type of trade must be considered if we aim to curb the illegal online trade in primates and its underlying impacts. The role of social media in the wildlife trade has become more apparent in recent years (Bergin et al., 2018; Chng and Bouhuys, 2015; Krishnasamy and Stoner, 2016; Moloney et al., 2021; Nijman et al., 2019; Siriwat and Nijman, 2018; Svensson et al., 2022). A critical aspect of this problem is that most of the primate-related content that garners millions of views and likes portrays these animals as pets or individuals in anthropogenic environments, often close to humans (Nunes et al., 2023). Such portrayal significantly influences public perceptions and potentially contributes to the trade (Aldrich et al., 2023). Online platforms that facilitate wildlife trade, such as social media platforms, should take responsibility not only for the illegal content advertised but also for the influence exerted on people (Morcatty et al., 2022b). Some platforms, including Facebook and Instagram, have joined the Global Coalition to End Wildlife Trafficking Online and aimed to reduce online wildlife trafficking by 80 percent by 2020. However, these platforms do not take proactive measures to counter crime, such as sharing all data with the police, due to their privacy policies. As a result, platforms often rely on deleting posts or user profiles (if they are detected) as their primary approach to addressing this issue. Taking advantage of this influence, they must support widespread campaigns on the consequences of the illegal trade and the complexity and responsibility assumed when purchasing a wild pet, as advocated by several authors (e.g., Nekaris et al., 2013; Svensson et al., 2022; Waters and El-Harrad, 2013).

Various strategies, such as machine vision models based on deep neural networks, have been developed and are continuously refined to detect and investigate posts of legally protected species, including primates, that are being sold online (Kulkarni and Di Minin, 2022). Because monitoring both domestic and international Internet trade requires a technologically innovative framework and constant improvement, a coordinated strategy could be strengthened within or parallel to CITES. This framework could serve as a common baseline for all countries, which could fortify it with additional mechanisms according to their domestic needs.

It is therefore essential to have a collaborative approach to monitor trade at both national and international levels to maximize effectiveness, including all relevant stakeholders, such as government agencies, law enforcement, conservation organizations, and private sector companies. By doing so, we can hope to reduce the harmful impact of the unsustainable online trade in primates and other affected taxa and promote primate species conservation.

Author statement

VN, TQM, MSS, KAIN conceived the study; MSS, VN, SS, KAIN conducted the literature survey; VN, TQM, HREB, HAR, AAng, AArd, SA, DB, SB, FBP, MC, ND, FES, KF, GF, AF, SDG, MFH, ER, BR, GRR, CRS, SS, PS, JHS, SAMMT, AST, AVW, AW, NY, MZ, MSS, KAIN provided country-level data on the online trade; TQM, HREB, FBP, MSS, MC, KAIN, VN analysed the data; VN, TQM, MSS, KAIN drafted the paper; HREB, FBP edited the paper, all authors commented on writing and approved final submission.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data availability

All data is available in the supplementary material

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envdev.2023.100925.

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