



Illegal trade in wild cats and its link to Chinese-led development in Central and South America

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Abstract: Seizures of hundreds of jaguar heads and canines in Central and South America from 2014 to 2018 resulted in worldwide media coverage suggesting that wildlife traffickers are trading jaguar body parts as substitutes for tiger parts to satisfy the demand for traditional Asian medicine. We compiled a data set of >1000 seized wild cats (jaguar [*Panthera onca*], puma [*Puma concolor*], and ocelot [*Leopardus pardalis*]) from 19 Central and South American countries and China. We ran generalized additive mixed models to detect trends in wild-cat seizures from 2012 to 2018 and assess the effects of socioeconomic factors of source countries and between those countries and China on the number of wild cats seized. Jaguar seizures increased over time, and most of the seized jaguar pieces were canines (1991 of 2117). Around 34% (32 of 93) of the jaguar-part seizure reports were linked with China, and these seizures contained 14-fold more individuals than those intended for domestic markets. Source countries with relatively high levels of corruption and Chinese private investment and low income per capita had 10–50 times more jaguar seizures than the remaining sampled countries. The number of Chinese residents in Central and South America was not significantly related to the number of jaguars seized. No socioeconomic factors influenced the seizures of puma and ocelots. Legal market chains may provide structure for the illegal chain; thus, the influx of illegal jaguar products is potentially a side effect of the economic partnership between Central and South American countries and China. Poverty and high levels of corruption in the source countries may motivate local people to engage in illegal activities and contribute to the growth of this trade. Supply-side interventions to curb this threat to Neotropical wild cats may include improved training for officials and promotion of governance and the value of protecting these animals to local people.

Keywords: jaguar fangs, *Panthera onca*, seizure, traditional Asian medicine, trafficking, wildlife trade

Mercado Ilegal de Felinos Silvestres y su Conexión al Desarrollo Encabezado por China en América Central y América del Sur

Resumen: La incautación de cientos de cabezas y colmillos de jaguar en América Central y América del Sur entre 2014 y 2018 resultó en una cobertura mediática mundial que sugirió que los traficantes de fauna están comerciando con partes de jaguar como sustituto de las partes de tigre para satisfacer la demanda de la medicina tradicional asiática. Recopilamos un conjunto de datos de más de mil felinos silvestres incautados (jaguar [*Panthera onca*], puma [*Puma concolor*], ocelote [*Leopardus pardalis*]) en 19 países de América Central y América del Sur y en China. Corrimos modelos aditivos mixtos generalizados para detectar las tendencias en las incautaciones de felinos silvestres entre 2012 y 2018 y para evaluar los efectos de los factores socioeconómicos de los países de origen y entre esos países y China sobre el número de felinos silvestres incautados. La incautación de

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artículos de jaguar incrementó con el tiempo y la mayoría de ellos fueron colmillos (1991 de 2117). Alrededor del 34% (32 de 93) de los reportes de incautación estuvieron vinculados a China y estas incautaciones tenían 14 veces más individuos que las incautaciones de artículos dirigidos al mercado doméstico. Los países de origen con niveles relativamente altos de corrupción y con inversión privada proveniente de China y con un bajo ingreso per cápita tuvieron de 10 a 50 veces más incautaciones de artículos de jaguar que los demás países muestreados. El número de residentes chinos en América Central y en América del Sur no tuvo una relación significativa con el número de jaguares incautados. Ningún factor socioeconómico influyó sobre las incautaciones de pumas y ocelotes. Las cadenas de mercado legales pueden proporcionar una estructura para la cadena ilegal; por lo tanto, la afluencia de productos ilegales de jaguar es potencialmente un efecto colateral de la colaboración económica entre China y los países de América Central y América del Sur. La pobreza y los altos niveles de corrupción en los países de origen pueden motivar a los habitantes locales a participar en actividades ilegales y a contribuir al crecimiento de este mercado. Las intervenciones del lado del suministro para disminuir esta amenaza para los felinos silvestres neotropicales pueden incluir mejoras al entrenamiento para los oficiales y el fomento entre los locatarios de la gestión y el valor de proteger a estos animales.

Palabras Clave: colmillos de jaguar, incautación, medicina tradicional asiática, mercado de fauna, tráfico, *Panthera onca*

摘要: 2014 至 2018 年间中南美洲缴获了数百个美洲豹头及犬齿, 引起了全球媒体的广泛关注。野生动物贩卖者可能正在试图将美洲豹作为虎的替代者, 以满足传统亚洲医药对后者器官的需求。我们从 19 个中南美洲国家及中国收集了超过 1000 起野生猫科动物缉获案件, 包含了美洲豹 (*Panthera onca*)、美洲狮 (*Puma concolor*) 及虎猫 (*Leopardus pardalis*) 三个物种。通过广义可加混合模型, 我们揭示了2012至2018年上述国家野生猫科动物缉获频次的变化趋势, 并对来源国社会经济因素对此趋势的影响进行了评估。结果显示美洲豹的缉获数量呈上升态势, 其中大部分被缴获的器官为犬齿 (1991/2117)。美洲豹器官的缉获报道中大约 34% (32/93) 与中国市场相关, 与其来源国市场相比, 涉及的个体数量超出 13 倍。在腐败严重、中国私人投资较多及人均收入较低的国家中, 美洲豹缉获案件数量超出其余国家 10 到 50 倍。中南美洲中国侨民的数量与美洲豹缉获数量之间无明显相关性, 同时也没有社会经济因素与美洲狮和虎猫的缉获数量直接相关。合法市场可以为非法贸易链条提供便利, 因此部分美洲豹制品的非法贸易可能是中南美洲国家与中国之间经贸往来的附带产物。部分国家的贫穷与腐败可能刺激当地民众参与非法贸易活动, 进而导致贸易量持续上升, 威胁新热带区野生猫科动物的生存。来源国可以通过对官员的进一步培训, 强化管理及提升当地民众的保护回报等方式加以控制和干预。

关键词: 美洲豹牙, 美洲豹 (*Panthera onca*), 查获, 亚洲传统医学, 走私, 野生动物贸易

Introduction

In 2018, a report claiming that wildlife traffickers in South America were possibly seeking jaguars to satisfy the demand for wild-cat body parts in Asia garnered worldwide attention (Fraser 2018). The story was prompted by the discovery of beheaded jaguars (*Panthera onca*) and ocelots (*Leopardus pardalis*) in Belize in 2017, the interception of almost 200 jaguar canines in Bolivia before shipment to China from 2014 to 2016, and the seizure of 120 jaguar canines in China, presumably in this same period. The article stimulated additional news on this trade (McKie 2018 [U.K.]; Hong Kong Animal News 2018 [China]) that reached a global audience.

Lions (*P. leo*), tigers (*P. tigris*), leopards (*P. pardus*), pumas (*Puma concolor*), and jaguars are threatened in part by international trade; this threat is most pronounced for tigers (Goodrich et al. 2015). Tiger parts, especially skins, teeth, meat, and bones, are in trade as decorations, jewelry, luxury food, and traditional medicine (Stoner 2014; Loginov & Loginova 2017). Much of the trade in tiger and lion body parts is driven by Chinese demand (Wong 2015) and, to a lesser degree, demand

in other Asian countries (Nijman & Shepherd 2015; Saif et al. 2016). For instance, individual wild cats or their parts (teeth and claws) accounted for 31% of all mammal seizures in airports worldwide; China was the most recorded destination (Center for Advanced Defense Studies 2018).

Trade in tiger and lion parts has been reported (Wong 2015; Williams et al. 2017), whereas little is known about the intensity of the emerging trade in jaguars and other Neotropical wild cats or about the market forces driving this trade. Consumer theory suggests the quantity ultimately sold in a market will be that in which the marginal benefit for consumers meets the marginal costs for the supplier in aggregate. Therefore, several variables from the supply and demand sides may influence market dynamics of the wild-cat trade. On the demand side, particularly in Asia, culture plays a significant role in shaping consumers' desire for wild cats in traditional medicine, as meat, or for social status (Moyle 2009; Nijman & Shepherd 2015; Williams et al. 2017). Growth of the overall economy and a boom in the urban middle class in China has increased demand. The middle class increased from 4% to 68% of the population, and urban household

income has almost doubled in the past 20 years, which has allowed these consumers to purchase a wider range of items (Barton et al. 2013). The demand for a given product may also be influenced by availability and price of substitutes for that item. Scarcity, due to the crackdown on trafficking in tiger parts (Kirkpatrick & Emerton 2010), may have raised the price of tiger parts to a level where consumers will accept potentially cheaper substitutes from other big cats, including those not native to Asia (Kernam 2010; Fraser 2018).

The cost of obtaining wild cats in source countries also influences establishment of the supply chain and prices paid along it (Wyatt 2009). Bottlenecks in the supply chain occur when products are moved up and capital is moved down to the different intermediaries involved (Raab & Milward 2003). Local people are typically responsible for sourcing wildlife parts. Their labor costs depend on how easy it is to access wildlife, how much they could earn in alternative economic activities, and the risk of being caught by local law enforcement (Barret et al. 2011; Biggs et al. 2017; Cooney et al. 2017). Setting up networks for transporting illegal products is usually difficult. Because covert trade networks must be concealed, stakeholders cannot count on a legal system to resolve contractual disputes. Therefore, trust becomes a key factor in reducing transaction costs and results in the majority of supply-chain transactions being done among ethnically homogeneous groups, in effect “trusting their own” (Raab & Milward 2003). Supplying the Chinese demand for wild cats may be facilitated by the Chinese diaspora (Skinner 2017). Recently, the Chinese influx to Central and South America has been associated with specialized occupations generated by new investments from China in these countries (Poston Jr & Wong 2016; Verheij 2019).

The presence of networks and flows of legal goods and capital between the consumer and the supplying countries can help reduce costs of illegal trafficking in at least 2 ways. First, illegal networks may find opportunities to exploit synergies with established, legal networks. Second, a strong flow of legal goods and capital can mask illegal flow and lower the cost of hiding trade (Raab & Milward 2003; Wyatt 2009). Chinese investment in Asia (~US\$500 billion) and Africa (~\$450 billion) has been substantial in the last decade (American Enterprise Institute 2018). Although smaller, Chinese investment in Central and South America, particularly in Brazil and Peru, has increased 10-fold over the last decade (~\$200 billion over the same period) and foreshadows potential growth in investment in illegal wildlife trade in this region.

That Chinese investment and migration and an existing overseas community may lead to an increase in jaguar trade is plausible. Thus far, however, this link has not been demonstrated empirically. The secretive nature of illegal wildlife trade means that researchers often resort to using indirect indicators (e.g., Ni et al. [2018] used

online reports of seizures). Lacking a comprehensive database on the quantity, prices, and supply-chain elements in the trade in wild cats from Central and South America to China, we used a data set on >1000 wild cat seizures reported from 2012 to 2018. We aimed to assess trends in wild-cat trade in Central and South America and the influence of the Chinese diaspora and the Chinese-led development on this market. We hypothesized that high availability of jaguars in natural areas, low gross national income (GNI) per capita, relatively weak law enforcement in source countries, large resident Chinese population and Chinese private investment in Central and South America, and high levels of legal exports from those countries to China contribute directly or indirectly to a low cost of supplying wild cats to the Chinese market that consequently increases illegal trade from the region. We also considered possible strategies to mitigate trade impacts on Neotropical wild cat populations.

Methods

Data Acquisition

We focused on 3 of the largest wild cats in the Americas, jaguar (body mass ~130 kg), puma (~80 kg), and ocelot (~20 kg). We collected data on seizures of these cats from online news articles, technical reports, and police reports published from January 2012 to March 2018 (seizures may be over-reported after March 2018 due to the reporting by Fraser [2018]; thus, we restricted our search to the period prior to that report). We used the search terms *seizure*, *arrest*, and the species' common and scientific names to locate reports in all 19 Central and South American countries (hereafter southern America), excluding Caribbean Islands. In these reports, the only non-American country that was mentioned more than once was China (see Results); thus, we used the same search terms to locate online reports in China. The search terms were translated into the relevant languages (Portuguese for Brazil, Dutch for Suriname, English for Belize, Mandarin for China, and Spanish for all other countries).

For each search, we checked all reports from the first 10 results pages, which totaled at least 100 sites consulted per species per country (El Bizri et al. 2015). For each report, we recorded the number of individuals seized, body parts involved, and final destination (domestic or foreign country). When the number of individuals was not specifically mentioned, we conservatively estimated the minimum number of individual cats required to obtain the number of reported body parts (i.e., 4 canines, 1 skull, 1 skin, or any amount of meat was considered 1 independent individual).

For each country and each species, we tallied the number of seizure reports and individual cats seized and

calculated the percentage of the total seizure reports that had links to China. These links could refer to Chinese nationals or descendants living in or visiting southern America being implicated in the seizure; confiscated packages with China reported as the end destination; explicit mentioning of China as the destination of the confiscated goods; or seizures made in China with explicit links to southern American countries. We use *Chinese involvement*, but recognize that few and specific individuals may be involved in this illegal trade, not Chinese society as a whole. We also do not imply the Chinese government is complicit in this activity.

To assess the market structures and dynamics of the wild-cat trade in southern America, we used the following as proxies: source country GNI per capita from 2012 to 2018 as a proxy for opportunity cost of local labor; species' extent of occurrence as an indicator of the costs of obtaining specimens; source country corruption perception index score from 2012 to 2018 as a proxy for effectiveness of local law enforcement (range: 0, highly corrupt, to 100, very clean); Chinese population resident in the source country in 2015 as an indicator of the cost of establishing local networks; flow of legal exports from source country to China from 2012 to 2018 as a proxy for costs of establishing networks for transportation of goods; and flow of Chinese private investment in southern American countries from 2012 to 2018 as a proxy for costs of establishing networks for transportation of capital.

We obtained data on the extent of occurrence for each species in each country from the IUCN Red List (IUCN 2019), on the Chinese population in southern American countries from the Central Intelligence Agency (2016), and on the corruption perception index from Transparency International (2018). We extracted the GNI per capita for each country from World Development Indicators (World Bank 2019) and Chinese foreign private investment and exports to China from the World Trade Organization (WTO 2019). All monetary units are in U.S. dollars.

Data Analyses

We used descriptive statistics to present the number of reports and individuals and number and types of items recorded as seized per species. To assess the difference in the number of individuals seized per report between seizures where China was implicated and seizures supposedly supplying the domestic demand, we used a *t* test with unequal variance because the homoscedasticity between groups was not met. We applied Shapiro-Wilk's test to test normality and Levene's test for homogeneity of variances.

To assess the influence of the socioeconomic variables on the number of individuals seized, we analyzed a balanced panel data in which the cross-sectional unit was

country and the time dimension was year. To address the time and spatial nonindependence (repeated measures) of the response variable, we applied generalized linear (GLM) and additive (GAM) mixed models. For that, we used GAM for location, scale, and shape (GAMLSS) (Stasinopoulos & Rigby 2007). A GAMLSS, similar to GLMs and GAMS, consists of a semiparametric statistical approach for univariate regression analysis that fits linear or nonlinear trends for the independent variables. Because no wild cat seizures were reported in some years in some countries, we fitted distribution families that balance the frequency of 0 s in the count data (such as the zero-adjusted gamma), provided by the GAMLSS. Because the socioeconomic factors were relative to the countries and because we may not have captured all intrinsic factors within a country that may influence the trade, country was set as a fixed effect, and, accordingly, the within effects for each country were accounted for in the model.

We used GAMLSS as described above to assess the influence of all socioeconomic variables compiled (see "Data Collection") on the number of individuals seized per year for each species in southern American countries from 2012 to 2018. In economic theory, trade usually has a nonlinear relationship with scale. Initially trade undergoes an economy of scale (process optimization), followed by a diseconomy of scale (external constraints limit productivity gains). Thus, we expected a similar trend for jaguar trade; the number of traded animals reaches an upper limit, similar to an asymptotic curve. Therefore, for economic variables and extent of distribution, we tested the fit of nonlinear effects with a penalized cubic splines function (cs) in which the nonlinear model is selected over a linear model only if the increase in fit is substantial enough to overcome the penalty. We tested for temporal autocorrelation in the panel data with the autocorrelation function (Acf), and there was no significant autocorrelation in the data. We also tested for multicollinearity among independent variables with a pair-wise correlation conducted with the function ggpairs. We considered any relationship between 2 variables with $R \geq 0.60$ collinear. Chinese foreign investment, exports to China, and jaguar extent of occurrence were collinear; thus, they were not included in the same model. For model selection, we ran the models with jaguar extent of occurrence. After selecting the best model, we reran it, replacing this variable with the Chinese foreign investment and the exports to China variables to obtain the relationship for these factors. For each model, we provide the estimates and SEs for the intercept and coefficients of each variable.

In a second analysis, we used a longitudinal approach to assess the trend in the number of jaguar, puma, and ocelot individuals seized in southern America over the sampled period. We pooled data from all countries per year and applied GAMLSS. We selected the family of

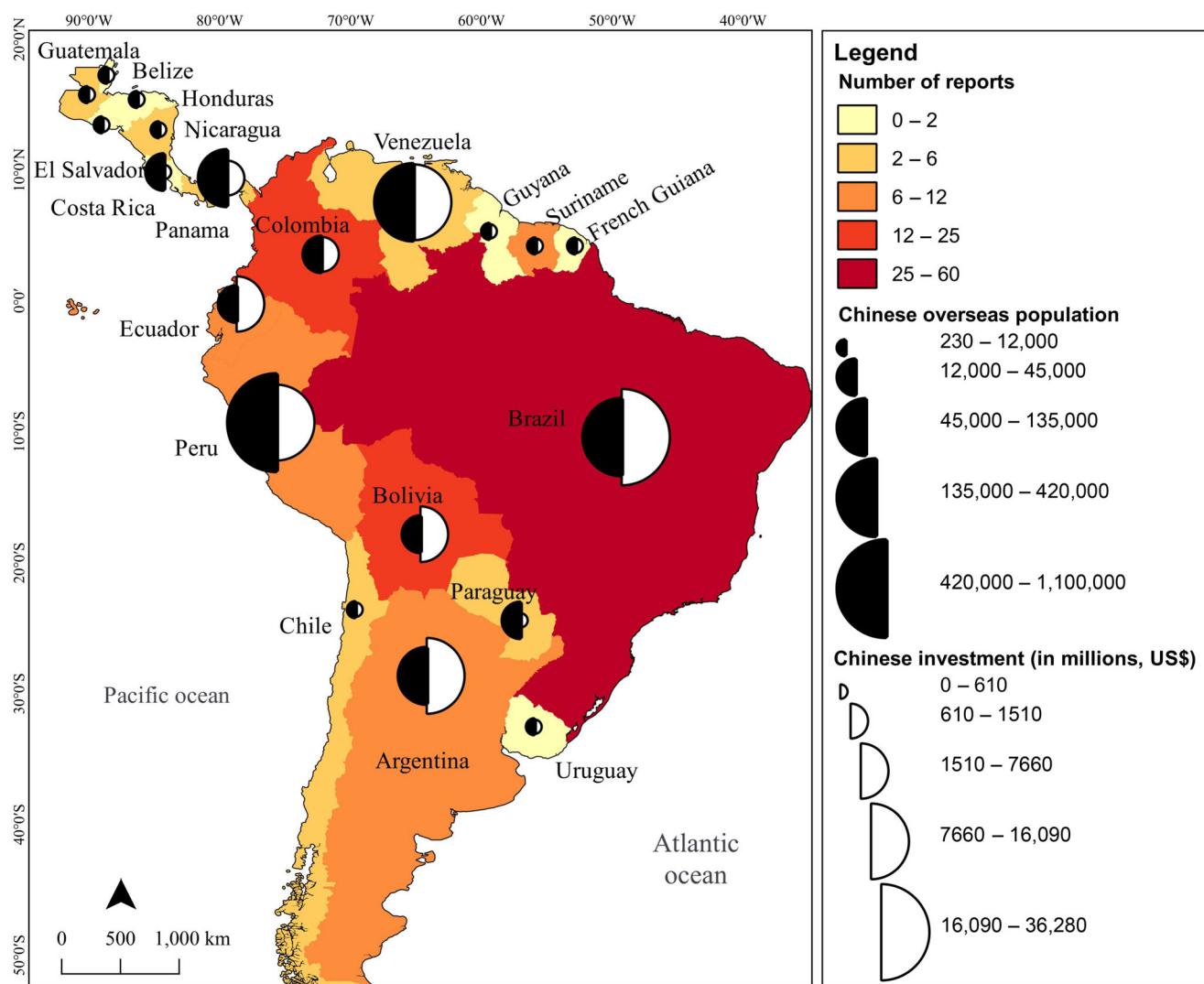


Figure 1. In Central and South America, number of reports of seizures of jaguar (*Panthera onca*) parts, number of resident Chinese, and amount of the Chinese private investment from 2012 to 2018.

distribution and final models based on the Akaike information criterion (AIC) for generalized models. Following the recommendations of Burnham and Anderson (2004), we considered models with good support and present in results all models with ΔAIC values <2 relative to the model with the smallest AIC (best-ranked model). We used *gamlss*, *GGally*, and *Forecast R* packages in R version 3.5.1 (<http://www.R-project.org/>) for statistical analyses and *Quantum GIS 2.18.9* (<https://quantum-gis.en.softonic.com/>) to create the map and obtain species' extent of occurrence for each country.

Results

We found 489 reports of trade in jaguars, pumas, and ocelots in 171 unique events involving ≥ 1 species (93 included jaguars, 46 included pumas, and 59 included

ocelots). These reports involved trade of at least 1038 individual cats (857 jaguars, 70 pumas, and 111 ocelots). Brazil had the most reports ($n = 60$, 35.1%), followed by Bolivia ($n = 25$, 14.7%), Colombia ($n = 18$, 10.6%), Peru ($n = 12$, 7.1%), and Suriname ($n = 10$, 5.9%) (Fig. 1 & Table 1). Two seizures of jaguars were reported in China (1.1%) that involved a minimum of 31 jaguars. For jaguars, most trade was in canines, followed by skins and heads. For pumas, most trade was in body parts (legs, claws, and tails), followed by whole bodies, and for ocelots, most trade was in live individuals (Table 2). When pooling all southern American countries, the number of jaguars seized annually (Fig. 2 & Table 3) and reports of jaguar seizures increased ~ 200 -fold and 5-fold, respectively, over the assessed period (Fig. 2 & Table 3). Conversely, seizures of pumas or ocelots remained stable at a mean of 7 and 10 individuals seized annually (Table 3).

Table 1. Data on extent of occurrence of 3 wild cats in Central and South American countries and the socioeconomic factors tested in the generalized additive models for location, scale, and shape (GAMSS).

Country	Extent of occurrence (in 1000 km ²)			Number of reports			Number of individuals			Corruption perception index	Gross national income per capita (US\$)	Exports to China (millions US\$)	Chinese investment (millions US\$)	Resident Chinese population
	jaguar	puma	ocelot	jaguar	puma	ocelot	jaguar	puma	ocelot					
Argentina	44.1	2428.0	180.0	7	0	5	0	5	0	35.7	19,011	4641.333	3990	120,000
Belize	22.0	23.0	23.0	2	1	0	1	1	13	38.1	7828	0	0	1930
Bolivia	732.4	1098.6	978.6	25	482	1	13	33.1	44	6401	435,667	748	30,000	400,000
Brazil	4603.7	8515.8	8279.4	60	53	20	14	39.7	44	14,823	39,410	7236	10,000	25,000
Chile	0.0	378.1	0.0	5	1	5	1	69.4	7	22,122	17,568.33	770	200	45,000
Colombia	854.2	1138.9	1010.1	14	7	3	10	36.5	10	12,879	17.97	470	200	45,000
Costa Rica	34.1	51.1	51.1	1	1	0	0	55.5	0	14,682	0	2157	716,333	30,000
Ecuador	94.5	283.6	283.6	8	1	0	6	32.7	6	10,536	6999	0	0	500
El Salvador	0.0	21.0	0.0	2	0	0	2	36.9	0	7235	0	700	1000	1000
Guatemala	49.5	108.9	108.9	4	3	2	0	29.2	0	7054	0	375	2919	530
Guyana	215.0	215.0	215.0	0	0	0	0	31.8	0	4279	0	350	530	530
Honduras	44.8	112.1	112.1	2	1	2	1	28.8	1	27.0	4788	0	530	12,000
Nicaragua	65.2	130.4	130.4	4	5	3	1	37.2	0	20,728	0	503	135,000	40,000
Panama	37.7	75.4	75.4	3	3	0	0	26.9	0	11,071	26.333	0	0	1,100,000
Paraguay	203.4	406.8	406.8	4	5	0	0	36.7	19	12,093	9169.667	3346	7885	7885
Peru	642.6	1285.2	1285.2	12	12	5	19	39.1	0	14,414	0	0	0	226
Suriname	163.8	163.8	163.8	10	11	2	0	71.8	0	19,945	1145.667	0	0	420,000
Uruguay	0.0	22.0	0.0	0	0	0	0	18.2	1	17,703	0	2713	2713	226
Venezuela	608.0	912.1	912.1	6	1	2	1	—	—	—	—	—	—	420,000
China	0	0	0	2	31	0	0	—	—	—	—	—	—	—
Total	—	—	—	171	857	70	111	—	—	—	74,910.33	24,088	2,381,990	—

Table 2. Data on specimens of 3 wild cat species seized from 2012 to 2018 in Central and South American countries.

Species	Number of specimens (no. reports)	Number of countries (%)	Number seized by type						
			tooth	skin	live animal	head or skull	body	other*	total
Jaguar	857 (93)	15 (79)	1991	54	19	28	20	5	2117
Puma	70 (46)	11 (58)	8	12	15	3	15	18	71
Ocelot	111 (59)	12 (63)	4	33	36	3	1	27	104
Total	1038 (171)	-	2003	99	70	34	36	50	2292

*Legs, claws, tails, and meat.

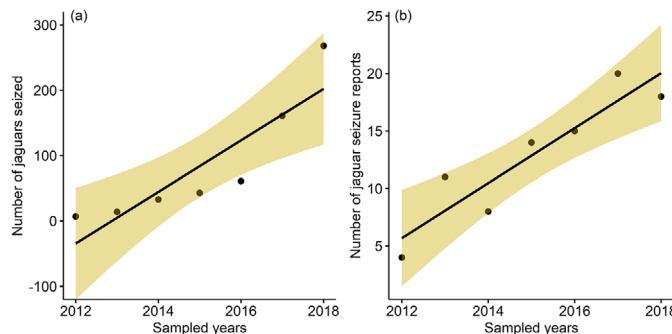


Figure 2. Temporal trend in (a) number of individuals and (b) number of reports of jaguar parts (*Panthera onca*) seized in all Central and South American countries from 2012 to 2018 (shading, 95% CI). Statistical details related to these models are given in Table 3.

Table 3. Details of the best-fit models using generalized additive models for location, scale, and shape (GAMLSS) for each response variable, for the temporal trend in the number of individuals seized, and for the relationship between the number of individuals seized per country and socioeconomic factors.

Response variables ^a	Predictor variables ^b	Estimate	SE	t	p	Family ^c	ΔAIC ^d
Temporal trend in seizures over the monitored period							
<i>N</i> reports of seized jaguars	intercept	-4808.8	768.8	-6.3	^e	NOR	11.23
	year	2.39	0.38	6.3	< 0.001 ^e		
<i>Individual</i> jaguars seized	intercept	-0.01	0.02	-43.2	0.01 ^c	NOR	32.8
	year	3.94	0.91	43.3	0.01 ^c		
<i>Individual</i> pumas seized (model 1)	intercept	1158.6	1316.2	0.9	0.42	NOR	1.27
	year	-0.57	0.65	-0.9	0.43		
<i>Individual</i> pumas seized (model 2)	intercept	7.14	1.37	5.2	< 0.001 ^e	NOR	0
	(null model)	—	—	—	—		
<i>Individual</i> ocelots seized (model 1)	intercept	-3874.8	2344.5	-1.7	0.17	NOR	0.31
	Year	1.93	1.16	1.7	0.17		
<i>Individual</i> ocelots seized (model 2)	Intercept	11.29	2.7	4.11	0.01 ^c	NOR	0
	(Null model)	—	—	—	—		
Socioeconomic factors related to the trade							
<i>Individual</i> jaguars seized	Intercept	2.23	0.384	5.8	< 0.001 ^c	ZAGA	11.02
	cs(jaguar distribution)	0.004	0.00006	6.0	< 0.001 ^c		
	cs(Chinese private investment)	0.0003	0.00002	13.3	< 0.001 ^c		
	Corruption Perception Index	-0.413	0.010	-3.9	< 0.001 ^c		
	Gross National Income per capita	-0.0009	0.0003	-3.2	0.002 ^c		
	Exports to China	0.0002	0.0001	-1.0	0.31		
	Chinese population	-2.3e-08	3.2e-07	-0.07	0.94		
<i>Individual</i> pumas seized	Intercept	0.089	0.078	1.1	0.26	NOR	53.4
	puma distribution	0.0003	0.00004	7.9	< 0.001 ^c		
<i>Individual</i> ocelots seized	Intercept	0.457	0.057	8.0	0.001 ^c	ZAGA	6.0
	cs(ocelot distribution)	0.0002	0.00002	10.2	< 0.001 ^c		

^aLink function log (ln).

^bNonlinear effect was fit with cubic splines (cs).

^cAbbreviations: NOR, normal distribution; ZAGA, zero-adjusted gamma distribution.

^dDifference between the selected model in relation to the second best-ranked model.

^eSignificant values (p < 0.05).

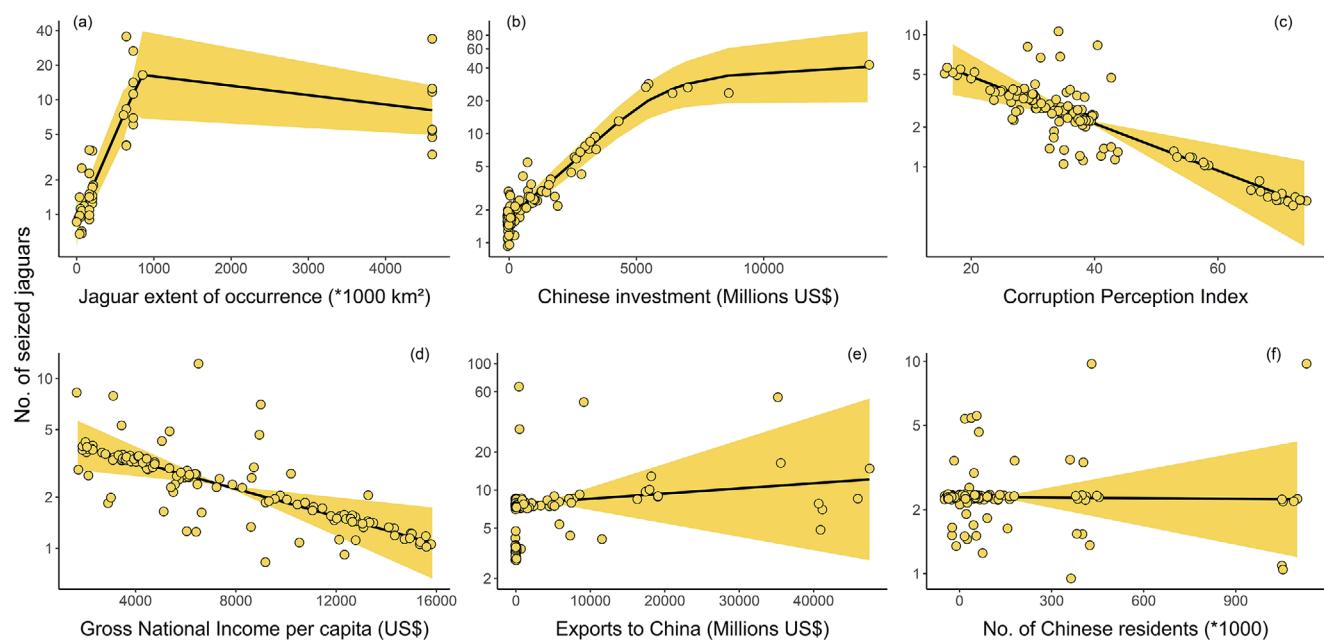


Figure 3. Relationship between the number of jaguar (*Panthera onca*) parts reported as seized in 19 Central and South American countries (2012–2018, see Table 1) and the countries' attributes: (a) jaguar extent of occurrence, (b) Chinese private investment, (c) corruption perception index (0 = highly corrupt, 100 = very clean), (d) gross national income per capita, (e) value of goods exported to China, and (f) resident Chinese population (shaded area, 95% CI). Original values are plotted on a log-transformed (\ln) y-axis. Statistical details related to these models are given in Table 3.

Almost one-fifth (32 of 169) of the reports from southern America specifically referred to China; all 32 reports referred to jaguars. Seven reports referred to international trade without specifying a destination country, and 1 report referred specifically to Italy. Five of these 8 reports referred to jaguars. For the 6 countries with the most reports, 30% of the reports specifically referred to China as a destination country, ranging from a high of 76% for Bolivia (19 of 25) to a low of 6.5% for Brazil (4 of 61). Seizure reports where China was implicated, on average, involved more individual jaguars than reports that did not refer to international trade, which more likely referred to domestic trade (means of 28 vs. 2, respectively; $t = 6.45$, $df = 55$, $p < 0.001$).

For all cat species, the number of individuals seized was positively correlated with their extent of occurrence within each country (Table 3). Countries with a large number of jaguars seized had a relatively high amount of Chinese private investment and had relatively low corruption perception index scores and GNI per capita (Fig. 3d & Table 3). The amount of exports to China and the number of resident Chinese people were not significantly related to number of jaguars seized (Fig. 3e-f & Table 3). No variable other than extent of occurrence was retained in the best-fitted model for pumas and ocelots (Table 3).

Discussion

Long-term efforts to conserve populations of wild cats in southern America may be threatened by a new wave of trade for local and international consumption (Nuñez & Aliaga-Rossel 2017; Braczkowski et al. 2019; Verheij 2019). Our findings indicated a recent increase in trade in jaguars and significantly less and stable trade in pumas and ocelots over the 6-year study period.

Experts from Bolivia, Suriname, Belize, Costa Rica, Panama, and Honduras claim there may be Chinese or Asian involvement in trade in wild cats (Kernam 2010; Nuñez & Aliaga-Rossel 2017; Reuter et al. 2018). The marked proportion of analyzed reports on jaguar seizures that explicitly mentioned China as an end destination or had Chinese nationals implicated in the seizure supports the contention that jaguars may be hunted to meet demand in China or originated from the Chinese diaspora in southern America (Kernam 2010; Verheij 2019). Seizures linked to China contained significantly more jaguar individuals, meaning this demand may be more critical than the domestic demand and has great potential to reduce jaguar populations.

We found that some Chinese-related market forces associated with the supply side of the chain and socio-economic factors from southern American countries were

related to variation in the numbers of jaguars seized. We confirmed the hypotheses that larger jaguar extent of occurrence and Chinese private investment in the countries are related to an increase in the trade in jaguars and that increases in the corruption perception index and GNI per capita are associated with lower trade rates. We did not confirm our hypotheses that exports to China and presence of Chinese residents contribute to the establishment of the jaguar market chain.

Transportation of product and capital is the key to success of any market chain (Wyatt 2009). The positive relationship between the number of jaguars seized and the amount of Chinese private investment may indicate that the legal market chain may provide structure for the illegal chain. Once the supply chain is built, it facilitates the trade in other illegal wildlife products. For instance, scales of African pangolins were initially traded to Asia for medicine, but afterward, sellers took advantage of the established chain to sell the species' meat, increasing hunting pressure (Challender et al. 2014).

High levels of rural poverty and corruption in developing countries may lead to the involvement of local people in illegal activities. The pursuit of financial improvement or social standing is one of the main motivations for poaching in rural communities (Cooney et al. 2017), and the lack of local governance and absence of institutions to properly manage the natural resources hinders long-term strategies for wildlife conservation (Barret et al. 2011). This is corroborated by the strong relationship we found between the corruption perception index and GNI per capita with the number of jaguars seized, which indicates the need to prioritize interventions on the supply side to generate potential reductions in jaguar trade in the region. Less corruption, and consequently more effective law enforcement, may increase in costs to people engaging in illegal activities by increasing the chances of successful prosecution with penalties (Cooney et al. 2017). Thus, as we expected, the combination of weak governance and limited sources of income in the rural areas of southern American countries, which contain vast tropical forests, may have promoted the establishment of hidden supply chains for jaguar trafficking in the region.

Because in our models the number of Chinese residents in the sampled countries did not have a significant effect, the Chinese connection to jaguar trade may be related to the more recent influx of Chinese people encouraged especially by new investments (Verheij 2019). New foreign visitors may still have fresh contacts with the Asian market and promote influxes of people and products. Conversely, long-established foreign descendants may have integrated into the local culture and lifestyle and may have less contact with people in their native country (Skinner 2017). Furthermore, as a high-end jewelry or decoration product, jaguar teeth may be more sought after by wealthy tourists or elites living in

Asia than by working-class immigrants, as in the ivory market (Gao & Clark 2014).

The main driver of trade in tiger parts is the belief held by some Chinese that the species' bones contain medicinal attributes. With the demise of tigers, body parts of other big cats, including leopards and lions, are increasingly being used as substitutes (Williams et al. 2015). More recently, jaguars were specifically alluded to as a substitute species (Nuñez & Aliaga-Rossel 2017; Reuter et al. 2018; Verheij 2019). Tiger and lion canines may also be used occasionally for medicinal purposes, but this is less common (Xin et al. 2017). Because the trade we examined seems mostly to target jaguar canines, jaguars do not appear to be a replacement for tigers in the medicinal bone market (Fraser 2018). Some of the jaguar teeth seized were carved for the jewelry market, indicating that those jaguar canines may play a role in the Asian market as jewelry or amulets. Big cats are frequently associated with strength, and their body parts are used or kept by people for imbuing personal and spiritual power (Williams et al. 2017; Kelly 2018; Braczkowski et al. 2019). Decoration and collection markets for wildlife-derived products are often rarity driven (Phelps et al. 2014), and jaguar pieces may infuse novelty to this market. For instance, in the orchid trade, mass-market buyers choose species to buy based on quality and beauty, whereas collectors look for rare species, including wild-harvested specimens (Hinsley et al. 2015). Thus, jaguar canines are likely substituting for teeth of tiger, lion, and other cats (Nowell 2000; Nijman & Shepherd 2015; Williams et al. 2017). Further research efforts on the cross-price elasticity of demand for jaguar and Asian and African cat species are urgently needed to determine whether jaguars are market complements or substitutes for tigers or lions in the Asian market.

The influx of illegal jaguar products is likely a side effect of the economic partnership between southern American countries and China and the high corruption rates in the supply-side chain. Reducing bilateral economic relations is not a viable strategy. Increased surveillance and improved cooperation between countries trading with China are needed to curb this threat. For processed wildlife products, there is a higher probability of detecting or confiscating illegal items close to the source or in transit (Center for Advanced Defense Studies 2018). After teeth are carved or added to jewelry pieces, it may be difficult to recognize and identify the species from which they were obtained. Thus, at the end of the chain, these products could be easily laundered as a legal item (Wyatt 2009). Plausible interventions on the demand side include the development of awareness campaigns in China regarding the illegality of and conservation problems related to the item and changing consumer perceptions regarding the possession of the product (Hall et al. 2008).

Supply-side interventions include strategic alliances among southern American countries to amend the gaps in current legislation, increase border controls, and strengthen surveillance in the source countries. Community-level interventions that empower and engage local communities as active and motivated stakeholders in law enforcement are a cost-effective and often less corruptible alternative for low-income countries (Biggs et al. 2017; Cooney et al. 2017). Strategies that increase the income in rural areas and the value of the presence of the wildlife, through, for example, ecotourism and forest-product extraction, may offer incentives for people to not involve themselves in illegal activities (Biggs et al. 2017; Cooney et al. 2017).

The magnitude of the tooth jewelry market has not been estimated for wild cat species, especially because of the difficulty in accessing this illegal and restricted activity (Phelps et al. 2016; Nijman et al. 2019). The general jewelry market in China has grown in the last decades (\$77 billion gross in 2012) (Hsu et al. 2014). We advocate for the establishment and improvement of comprehensive databases on hunting and trafficking of wild cats from southern American countries, improved training of officials so that they can recognize objects containing wildlife, and investment in research on wildlife trafficking. We did not explore demand-side factors of the jaguar market, and these drivers need further research.

Ours is the first large-scale assessment that shows the coverage and some drivers of the international trade in jaguars in southern America. We acknowledge the limitation posed by gathering data only from online sources in representing the real number of seizures and the actual number of individuals traded, especially considering the possible effects of distinct surveillance efforts among countries and the tendency to over-report seizures implicating international countries. Seizure reports and media items have been used frequently and are claimed to be among the few sources available through which to assess hidden markets in wildlife (Ni et al. 2018) or sensitive illegal behaviors, such as hunting (El Bizri et al. 2015). They can be an important source for a first diagnosis of trade in wild cats, especially considering the absence of an official seizure database in most of the involved countries and the high risk and difficulty of conducting market surveys and interviews with traffickers.

In addition to providing numbers and a perspective on the state-of-the-art and drivers of the jaguar trade in southern America, we sought to increase awareness of this emerging threat and to suggest priorities for new assessments. Besides wildlife trade, Neotropical wild cats are threatened throughout their distribution by habitat loss and fragmentation, road mortality, and conflicts with humans due to livestock predation (Paviolo et al. 2016; Verheij 2019). Unlike these other threats, trade in Neotropical cats is understudied (Kernam 2010; Reuter et al. 2018; Verheij 2019). Thus, understanding further

features of this market, such as its magnitude and stakeholders involved, is crucial for developing strategies to address this threat and promote conservation of these threatened species.

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