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Comparing environmental and socioeconomic drivers of illegal capture of wild birds in Brazil

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Summary

In order to conserve species exploited by trafficking, governmental actions should be directed to source areas, aiming to reduce or eliminate illegal and indiscriminate trapping. However, few studies have diagnosed and prioritized the most relevant drivers of the illegal capture of wild animals. In this study, we aimed to evaluate the main drivers of the illegal capture of wild birds in Brazil. A literature review and a multivariate modelling approach indicated the economic, social and environmental factors that display the greatest influence in boosting this illicit activity worldwide. Our search revealed seven drivers of illegal wildlife capture addressed by researchers in studies carried out in source countries. This is the first broad-scale study in Brazil showing that higher native vegetation coverage and greater proximity to protected areas were the main drivers of illegal wild bird capture for trafficking. Thus, actions that aim to protect species threatened by trafficking require a multidisciplinary approach encompassing social, economic and environmental factors.

Introduction

Wildlife trafficking is one of the most widespread and lucrative illicit activities worldwide (Lawson & Vines 2014, UNODC 2016), comprising the capture, poaching and trade of living and dead wildlife for pets, sport, human consumption and ornamental, medicinal or religious purposes (Barber-Meyer 2010, Hansen et al. 2012). Aside from the legality issues (see Lawson & Vines 2014, Ratchford et al. 2013), unregulated wildlife trade generates serious environmental consequences, including the introduction of exotic species, spread of wildlife diseases, disruption of ecosystem processes and ecological services such as pollination, seed dispersal and population control of other animals and, in the medium and long term, extinction of exploited species (e.g., Dai & Zhang 2017, Fernandes-Ferreira et al. 2012, Nascimento et al. 2015). Although it is difficult to measure the number of illegally traded animals (Barber-Meyer 2010, Duffy 2016), characterizing the origin of the trafficking chain could aid in efforts to reduce or eliminate indiscriminate captures (Lawson & Vines 2014, Primmer et al. 2000).

Brazil has one of the richest avifaunas in the world, with many species currently threatened by illegal trade (Freitas et al. 2015, Marini & Garcia 2005) including, for example, the family Thraupidae (e.g., Destro et al. 2012, Fernandes-Ferreira et al. 2012, Licarião et al. 2013). The interaction of factors in the commercial chain of illegal trade begins in rural regions and farmland areas (Fig. 1), where collectors capture animals using various techniques (see Souto et al., 2017). Once illegally captured, most birds are delivered to traders who negotiate the sale of specimens in public and street markets (Licarião et al. 2013, Regueira & Bernard 2012), or they are sent to both authorized and unauthorized breeders and enterprises by intermediary traffickers (Destro et al. 2012, Kuhnen et al. 2012) who subsequently trade them mainly through the Internet (Ratchford et al. 2013, Souto et al., 2017). Although the stages involved in wild animal trafficking, from capture in the wild to final consumers, are relatively well understood in Brazil, there is still incomplete information available on some links in this chain and on the factors underpinning illegal trade, which makes it difficult for the government to control this activity.

For instance, illegal captures of wild birds and their trade are widespread throughout Brazil (Alves et al. 2013a), yet identifying source areas is not an easy task, as the site of apprehension by law enforcers generally differs from that of capture (Hernandez & Carvalho 2006). However, it is possible to infer that most illegally traded animals come from the north, northeast and mid-west regions of Brazil (e.g., Destro et al. 2012, Ferreira & Glock 2004, RENCTAS 2001) and are then smuggled to both the south and southeast regions along federal highways (Supplementary Material S1, available online). Rivers are equally utilized routes for the sale

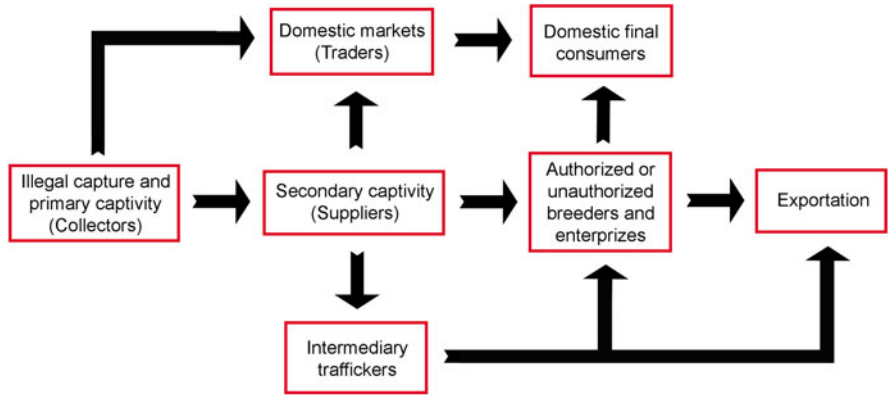

Fig. 1. Wildlife trafficking chain in Brazil from capture in the wild to final consumers.

of trafficked animals in the Amazon states (north region of Brazil); however, birds are less represented among the total number of wild vertebrates trafficked and seized through these routes (Nascimento et al. 2015). Much like other countries that report issues with illegal wildlife trade (e.g., Dai & Zhang 2017, Daut et al. 2015, Gastañaga et al. 2011), the main purpose for illegally captured wild animals in Brazil is internal trade (Destro et al. 2012).

Despite Brazil's vast territory and extreme socio-environmental complexity, socioeconomic factors have been used to empirically explain and characterize the regional wildlife trade in the country (e.g., Alves & Rosa 2010, Regueira & Bernard 2012). In order to better understand the nationwide dynamics of wildlife trafficking and to propose effective measures for the federal protection of exploited species, it is necessary to aggregate local socio-environmental peculiarities (e.g., Alves et al. 2016, Gama & Sassi 2008, Licarião et al. 2013). Thus, the present study aimed to analyse the drivers that are most influential in illegal animal captures in source countries worldwide and to evaluate, at a broad scale, which of these most often contribute to illegal bird capture in Brazil. The specific objectives were to map the main regions that supply trafficked wild animals in Brazil and to assess the factors that promote this illicit activity in each region of the country. This is the first broad-scale study aiming to identify the main drivers of illegal animal captures in source countries, which, if primarily considered in efforts for the regulation of animal trafficking, would render public policies towards overexploited species conservation more successful.

Methods

Selection of source municipalities and main drivers of illegal capture

An extensive literature search was carried out using the Portal de Periódicos (Brazilian National Electronic Library; CAPES 2016) to identify papers related to trafficked wild animals in Brazil. The terms 'illegal' AND 'trade' AND 'Brazil' were used, without restricting journal, language, year of publication or information platform. A total of 139 papers were identified. The Google Search Engine (www.google.com), in both Portuguese and English, was also used to search for grey literature, such as newsletter articles, magazines and newspapers, published abstracts, books, book chapters and technical reports, which added another 60 publications. Seven drivers cited by researchers that could explain the practice of illegal wild animal capture in source countries were identified (Table 1). The literature review was further used to list the source municipalities for animal trafficking in Brazil (i.e., the main municipalities described in the literature as wild animal suppliers, referred to herein as source areas; Supplementary Material S1 & S2).

To obtain data for the analyses of these seven drivers, the most recent decennial census in Brazil (year 2010) was used as reference – except for native vegetation coverage (NVC) and road systems data, which were available for 2008. All geographic databases were obtained from Brazilian governmental websites, such as the Ministry of the Environment (MMA 2008, 2017), Ministry of Transport (MT 2008), the Instituto Nacional de Pesquisas Espaciais (INPE 2008) and the Instituto Brasileiro de Geografia e Estatística (IBGE 2010a, 2010b), or international organizations such as the United Nations Development Programme (UNDP 2010) (Table 1). Environmental protection areas were excluded from the analysis regarding quantitative protected areas (PAs), as this category displays a low degree of land-use restriction, which is closer to a mechanism for land-use management than an actual PA (Rylands & Brandon 2005). A combination of distribution maps for the ten most seized native bird species in Brazil (Supplementary Material S3), according to a survey conducted by Destro et al. (2012), was used as a surrogate to obtain a richness map of the most trafficked species. Thus, exotic and domestic species listed by Destro et al. (2012) were excluded, as well as animals belonging to the other vertebrate classes. The ten bird species used here belong to the Thraupidae (7), Passerellidae (1), Icteridae (1) and Cardinalidae (1) families, which are highly coveted by traffickers due to their beautiful plumage, shape and singing ability (e.g., Fernandes-Ferreira et al. 2012, Licarião et al. 2013, Teixeira et al. 2014). Moreover, species like the saffron finch (*Sicalis flaveola*) and red-cowled cardinal (*Paroaria dominicana*) are also used in fights, as roosters are used in cock-fighting (Alves et al. 2010, Gama & Sassi 2008, Souto et al., 2017). In fact, researchers have pointed to a need to understand the scale and breadth of the illegal trade of species that are not global conservation flagships, since these categories represent a significant proportion of live wildlife seizures in tropical countries and often have no guarantee of financial resources for protection (Gray et al. 2017). The ten species accounted for over 60% of the wild birds seized in the country from 2005 to 2009 (Destro et al. unpublished data 2012). In this sense, although all are categorized as being of Least Concern by the International Union for Conservation of Nature (IUCN 2016) and present a wide geographic distribution (Sick 1997), many have suffered severe population reductions, and some have already become locally extinct (Fernandes-Ferreira et al. 2012). We obtained the distribution polygons of the most seized species

Table 1. Drivers addressed by researchers that could explain the practice of illegal wildlife capture in source countries.

Driver	Theoretical background	Reference author(s)	Reference year	Data source
Remnants of natural vegetation from Brazilian biomes	A greater numbers of specimens and, consequently, higher capture rates are expected in regions with more available habitats	Santos and Araujo (2015)	2008	Amazon: INPE (2008); other biomes: MMA (2008)
Municipal Human Development Index	Higher capture rates are expected in regions with lower education and income rates	Godoy and Matushima (2010), Regueira and Bernard (2012), Santos and Araujo (2015)	2010	UNDP (2010)
Municipal gross domestic product	Higher capture rates are expected in poorer regions	Godoy and Matushima (2010), Regueira and Bernard (2012), Santos and Araujo (2015)	2010	IBGE (2010a)
Most trafficked species richness	Higher capture rates are expected in regions presenting greater species richness	Atuo et al. (2015)	Current	BirdLife (2016)
Federal, state and municipal protected areas (excluding EPAs)	Higher capture rates are expected in less protected regions	Wright et al. (2001)	2010	MMA (2017)
Road network	Higher capture rates are expected in more accessible regions	Alves et al. (2013a), Clements et al. (2014)	2008	MT (2008)
Municipal population density	Higher capture rates are expected in more densely populated regions	Santos and Araujo (2015)	2010	IBGE (2010b)

EPA = environmental protection area.

from the BirdLife website (BirdLife 2016) and all geoprocessing steps were performed using ArcGis 10.2.2 software (ESRI 2014).

Multivariate modelling

The values corresponding to the seven selected predictors were extracted for each of the 5563 Brazilian municipalities: (1) percentage of NVC; (2) Municipal Human Development Index (MHDI); (3) municipal gross domestic product (GDP); (4) most trafficked species richness (RIC); (5) percentage of PAs; (6) road density ($m^2/m^2 \times 1000$) (ROA); and (7) municipal population density ($person/km^2$) (MPD).

Multivariate modelling approaches were applied using a general discriminant analysis (GDA), a multivariate statistical technique that uses information available from a group of independent variables with normal distribution to predict the value of a categorical dependent variable (Ragsdale 2001). The GDA was performed using the Statistica 7.0 software first for Brazil nationwide and then by individual units of the north, northeast, mid-west and south/southeast regions. We grouped the south and southeast regions together due to their low incidence of municipalities with illegal capture and because they are considered to be the main consumers for Brazilian trafficked wildlife nationwide (e.g., Destro et al. 2012, Ferreira & Glock 2004, RENCTAS 2001). As the dependent variable, all Brazilian municipalities were categorized into two groups as binary factors: (1) source areas – main municipalities for illegal wildlife capture according to the literature; or (2) control group – the remaining municipalities. In this sense, the GDA was used to determine which independent variables (drivers) most contributed to the differences among groups (source areas and controls) (Malhotra 2001). To obtain simple correlations between the variables and the discriminant function (i.e., to identify which independent variables cause the discrimination between the dependent variables), we used factor structure coefficients, also called structure correlations or discriminant loadings. Positive factor structure coefficients indicate a positive correlation among variables and negative values represent a negative correlation. The metric is useful to assign substantive, meaningful labels to the discriminant functions, akin to the interpretation of factors in a factor analysis (Hair et al. 2009). Variables that reached factor structure coefficients >0.4 were considered relevant (Hair et al. 2009). We standardized all data for the statistical analyses and used a stepwise method, which considers the step-by-step inclusion of significant variables only (Hair et al. 2005). In addition, we used Wilks' λ statistic test in order to evaluate differences between means for each variable among groups, where $\lambda = 1$ indicates no significant difference (Subramanian et al. 2007).

Results

In total, 195 municipalities displaying incidences of illegal capture of wild animals were identified: 40 in the north, 71 in the northeast, 45 in the mid-west and 39 in the south/southeast regions (Supplementary Material S1 & S2). The R^2 obtained from χ^2 tests with successive roots removed (Table 2) explained between 3.48% (northeast) and 10.85% (mid-west) of the variation observed among dependent variables. The Wilks' λ statistic test indicated that, although significant, there is little difference between the source areas and control group.

Table 2. χ^2 tests with successive roots removed.

Region	Eigen-value	Canonical R	Canonical R^2	Wilks' λ	χ^2	df	p-value
Brazil	0.039	0.193	0.0372	0.963	210.521	4	<0.05
North	0.118	0.324	0.1052	0.895	49.409	5	<0.05
Mid-west	0.122	0.329	0.1085	0.891	53.198	2	<0.05
Northeast	0.036	0.187	0.0348	0.965	63.340	3	<0.05
South/southeast	0.101	0.302	0.0914	0.909	273.372	3	<0.05

Table 3. Factor structure coefficients of the variables nationally and in the four regions.

Variables	Brazil	North	Mid-west	Northeast	South/southeast	Sum
MPD	−0.114	0.110	−0.068	0.137	−0.028	0
GDP	−0.132	0.267	−0.017	0.146	−0.035	0
MHDI	−0.314	−0.321	−0.260	**0.679**	−0.163	1
NVC	**0.877**	0.144	**0.562**	0.200	**0.813**	3
ROA	**−0.447**	**−0.432**	−0.126	−0.297	−0.201	2
PA	**0.609**	0.050	0.126	**0.514**	**0.809**	3
RIC	−0.213	**0.493**	**0.539**	−0.049	−0.073	2

The most important variables are presented in bold (coefficients greater than ±0.4).
MPD = municipal population density; GDP = municipal gross domestic product; MHDI = Municipal Human Development Index; NVC = native vegetation coverage; ROA = road density; PA = protected areas; RIC = most trafficked species richness.

Environmental factors, such as NVC and PAs, were the most important drivers of illegal wild bird captures in Brazil, followed by ROA and RIC (Table 3). Socioeconomic factors, such as MPD, GDP and MHDI, had secondary or null roles. An exception was observed for the northeast, where the high MHDI was noteworthy as an important discriminant driver of illegal wild bird captures (see also Supplementary Material S4).

Discussion

Our study demonstrated on a broad scale that environmental factors were the most important drivers of illegal avifauna captures and not socioeconomic factors, reinforcing the need for multi-scale approaches in similar such studies (Cumming et al. 2015, McGarigal et al. 2016). Greater NVC was the most important driver of illegal wild bird captures in Brazil nationwide, as well as in the mid-west and south/southeast regions. This had been previously described in the Brazilian Cerrado, where the highest vegetation coverage was associated with greater biodiversity availability for harvesting by the resident population (Santos & Araujo 2015). In Iowa (USA), Haines et al. (2012) observed that poachers preferred to be active in areas next to forests and in riparian cover types containing variable topography. In addition, the higher concentration of PAs also boosts illegal capture in the country in its entirety, as well as in the northeast and south/southeast regions, probably due to a greater supply of specimens compared to unprotected sites, revealing a possible fragility of federal PAs regarding poachers or trappers (Carvalho Jr & Morato 2013, Tebaldi et al. 2012). In contrast, Wright et al. (2001) revealed that Neotropical parrot poaching was higher in unprotected sites when compared to protected sites. New studies are needed to elucidate the true role of PAs in the conservation of species exploited by trafficking.

ROA also influences illegal bird capture in Brazil, especially in the north (Brazilian Amazon), which has the lowest ROA in the country, although rivers are also important means of transport for trafficked animals (Nascimento et al. 2015). Large numbers of roadways and pathways favour animal capture and poaching (Haines et al. 2012, Maingi et al. 2012), since it is more convenient to transfer the animals to vehicles and trade them in public shops and street markets (Alves et al. 2013a, Shepherd et al. 2007), besides facilitating the access and escape of poachers (Webb et al. 2011). However, in the long term, regions that display lower highway concentrations tend to sustain larger stocks of targeted fauna, because roads make it easier to open forests for hunting and may also cause negative environmental effects, such as chemical and nutrient pollution, edge and barrier effects, animal car accidents, invasion of exotic species and other impacts on local soil, hydrology and aquatic ecosystems, especially if not previously planned for (Clements et al. 2014, Laurance et al. 2009). River routes were not included in our analysis, even though they are an important means of transport in regions such as the Amazon biome.

Species richness was also noteworthy as an important driver of fauna capture in the north and mid-west, as in African countries where poachers have focused efforts on areas that contain higher numbers of species and individuals (Atuo et al. 2015, Maingi et al. 2012). In fact, in the northern region of Brazil, most of the ten species display a marginal distribution to the eastern Amazon, coinciding with the location of source municipalities, while in the mid-west region they present a great overlap with the Pantanal biome, where most of the selected municipalities are located. Herein, we emphasize the limitations of our results, since the source areas used here came from bibliographical research, so that other relevant municipalities may not yet have been detected by enforcement efforts or research.

Contrary to our expectations, socioeconomic drivers were relevant only in north-eastern Brazil, one of the main supply regions of animals for the illegal wildlife trade (e.g., Destro et al. 2012, Godoy & Matushima 2010, RENCTAS 2001), comprising 36.41% of all summarized source municipalities. A positive relationship between source municipalities and MHDI was noted; illegal fauna capture occurred mainly in the municipalities presenting higher MHDI. This is contrasted with a common association between the high incidence of captive birds in areas with low socioeconomic index scores (Alves et al. 2013b, Regueira & Bernard 2012). In fact, previous studies have pointed out that socioeconomic factors are the best predictors of poacher participation in the avian trade in Brazil (e.g., Gama & Sassi 2008, Santos & Araujo 2015, Souto et al., 2017) and other developing countries, such as Mexico (González-Marín et al., 2016), Zimbabwe (Lindsey et al. 2011), the Democratic Republic of the Congo (Nasi et al. 2011) and Nigeria (Atuo et al. 2015). In this context, where high unemployment rates and low levels of formal education conditions prevail, activities related to the illegal bird trade would be very lucrative (Alves et al. 2013a) and would provide additional income sources to families (Souto et al., 2017). Brazil fits this description, presenting high social inequality, including in its main large cities (Regueira & Bernard 2012), and high biodiversity, with 1919 bird species catalogued so far (Piacentini et al. 2015) and many of them threatened (IUCN 2016).

A thorough look at the relationship between poverty and illegal wildlife consumption reveals that knowledge on this subject is limited and that conservationists should broaden their views of what constitutes illegal wildlife trade, what motivates people to hunt illegally and how to tackle the problem (Duffy et al. 2016). Thus, although the illegal wildlife trade is frequently characterized as the result of economic poverty or greed, links among wealth, poverty and engagement in the wildlife trade are usually far more complex (Duffy et al. 2016, TRAFFIC 2008). In fact, besides birds' colour, singing ability and behaviour, access to birds and cultural habits seem to have a direct influence on common bird captures in Brazil (Alves et al. 2010, Souto et al., 2017), making the internal trade in Brazil the main target for animals illegally collected from the wild (Destro et al. 2012). This interpretation was evident in our results, since the seven drivers explained between 3.48% (northeast) and 10.85% (mid-west) of the variation observed among the source areas and the control group, revealing the participation of other variables that are difficult to measure or describe in the literature. In summary, the demand for songbirds in Brazil presents a high cultural bias (Licarião et al. 2013, Souto et al., 2017) and is widespread among the local population independent of socioeconomic factors (Alves et al. 2016), making surveillance and enforcement difficult and time consuming (Silva & Bernard 2015). In fact, the low risk of detection, relatively small penalties and minimal consequences for perpetrating wildlife crime, allied with the lack of enforcement and basic governance structures of local authorities, constitute attractive incentives to participate in this illegal activity (Ratchford et al. 2013), although this is difficult to measure and evaluate.

In sum, our results highlight that conservation measures for trafficked bird species should incorporate interactions between environmental, cultural and socioeconomic drivers, promoting actions capable of reducing the current level of exploitation (e.g., Alves et al. 2013b, Atuo et al. 2015, Tella & Hiraldo 2014). Thus, in order to reduce illegal captures, it is essential to implement effective public policies that involve education, policing/enforcement, the creation of alternative sources of income and proactive ecosystem management and conservation (e.g., Fernandes-Ferreira et al. 2012, Santos & Araujo 2015, Souza & Alves 2014), while always considering a multiple spatial-scale approach (Cumming et al. 2015, McGarigal et al. 2016). Expert opinions suggest that only improving the incomes or livelihood status of harvester communities often does not reduce their participation in the wildlife trade (TRAFFIC 2008), and well-intentioned policies may collapse at a local scale and ultimately fail to reduce the risks associated with environmental insecurity and biodiversity exploitation (Gore et al. 2016).

In many countries, especially those located in tropical regions with great fauna diversity, the illegal commerce of wild animals removes many species from their natural environments and is certainly among the gravest threats to native populations (Alves & Souto 2015). We present a diagnostic method capable of discriminating drivers related to illegal bird capture in supply countries. However, other factors should be diagnosed and evaluated in future studies, especially those related to local and national governance power. In fact, the illegal wildlife trade requires broader debates on associated science and policy, since these debates have historically been focused on only a few high-profile species (i.e., rhinoceroses, tigers, elephants) and often overlook or combine complex actors, networks and contexts (Phelps et al. 2016). Understanding the dynamics related to the drivers of wildlife trafficking is part of this transnational effort aimed at better geographical allocation of conservation actions and resources worldwide, leading to more precise and effective public policies for wildlife crime prevention and control (Haines et al. 2012).

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S0376892919000316

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Ethical standards. None.

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