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Wildlife sinks: Quantifying the impact of illegal bird trade in street markets in Brazil

Rodrigo Farias Silva Regueira, Enrico Bernard *

Departamento de Zoologia, Universidade Federal de Pernambuco, Rua Nelson Chaves s/n, Cidade Universitária, Recife, PE 50670-420, Brazil

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ABSTRACT

Illegal wildlife trade is a widespread activity with direct impacts on biodiversity and street markets are frequently pointed out as hotspots in the wildlife trade route. However, due to its illegal character, it is difficult to accurately estimate how many individuals and how much money are handled by traders. Precise data on the number of individuals and species involved, and the drivers behind the illegal wildlife trade are essential for fighting it. We use the example of the metropolitan area of Recife, in northeastern Brazil, a well-known route of illegal wildlife in the country, to access the extent and impact street markets may have on biodiversity. We present quantitative and qualitative information on the illegal trade of wild birds in eight street markets in the area, indicating which species are preferred and why, estimating the number of animals and the volume of money involved, and quantifying the impact that the removal of those animals may have. We observed a high and diversified species offer, biased towards adult male songbirds, with birds of 15 families and 55 species on sale. Birds are kept in poor conditions and some individuals are sold for as little as US\$ 1.00. However, we projected that up to 50,000 wild birds may be sold annually in the markets surveyed, including possibly 16,800 individuals of *Sporophila nigricollis* (the yellow-bellied seedeater), the most frequently observed species. The activity is profitable and may deal with significant amounts of money (up to nearly US\$ 630,000.00/year). The numbers involved indicate that street markets are significant wildlife sinks, with a large and frequently ignored impact that must be taken into account in the control and conservation of the biodiversity, not just in Brazil but elsewhere.

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1. Introduction

Estimates indicate that wildlife trade is considered the third largest illegal trade in the world, behind drug and arms trafficking, and worth billions of dollars annually (Barber-Meyer, 2010). Illegal wildlife trade causes direct impacts on biodiversity, reducing some populations nearly to extinction (TRAFFIC, 2011). Data from 2008 indicate that 408 worldwide-threatened bird species are affected by hunting and capture for trade (Birdlife International, 2011). The trafficked animals may also represent a problem to human and livestock health, since they do not undergo sanitary inspections, representing potential vectors of diseases, such as yellow fever, avian influenza, rabies, toxoplasmosis, and tuberculosis (e.g. Bell et al., 2004; Borm et al., 2005; Weldon et al., 2004). Moreover, trade conditions are frequently degrading: animals are caged in overcrowded compartments, without water and food, and suffer stress, fights, mutilations and death (RENCTAS, 2001; TRAFFIC, 2011). Also, the surviving animals frequently suffer abuse with consequences such as the reduction of their life expectancy (Vanstreels et al., 2010).

Because wildlife trade is illegal in most countries, it is difficult to accurately estimate how many individuals and how much money are handled by traders, but street markets are frequently pointed out as hotspots in the wildlife trade route (e.g. Broad et al., 2003; Herrera and Hennessey, 2007; Nijman, 2010; Pereira and Brito, 2005; RENCTAS, 2001; Shepherd and Nijman, 2008; TRAFFIC, 2011; Whiting et al., 2011). There are some estimates on the numbers associated with the illegal wildlife trade, but with few exceptions (e.g. Shepherd and Nijman, 2008; Nijman, 2010; Whiting et al., 2011) the methodology used to obtain the data available is frequently not presented, making it difficult to check their accuracy. Precise numbers on animals dead by the traffic, for example, are scarce and difficult to measure; estimates point out that for each wild animal traded alive, 3 (Redford, 1992) to 10 (RENCTAS, 2001) other may have died. However, these numbers have a high degree of imprecision and must be considered with caution.

People involved in wildlife trade range from average citizen seeking ways to complement their income to professional traders (Nijman, 2010; Osterblom et al., 2011). In countries with high biodiversity and social inequality, the causes of illegal wildlife trade are frequently related to socio-economic characteristics of the country and its regions. Brazil fits this description: it is a mega-diverse country with high social inequality in all of its regions, including the main large cities. Wildlife trafficking is not typified

* Corresponding author. Tel./fax: +55 81 2126 8353.

E-mail address: enricob2@gmail.com (E. Bernard).

in the criminal Brazilian legislation, meaning that one can be prosecuted for owning or transporting wild animals without a legal permit (Brasil, 1999), but no one can actually be prosecuted for trafficking *per se*. The value of fines increases according to the amount of animals arrested or their conservation status but, in reality, prosecutors tend to consider wildlife trafficking as a minor crime in Brazil, so jail time (which rarely happens) is short and penalties are frequently replaced for softer ones, such as community services. Consequently, the illegal wildlife trade turns up as a source of easy profit in Brazil (RENCTAS, 2001), since there is a demand for this kind of ‘product’ and authorities fail to repress this activity, what also happens elsewhere (e.g. Nijman, 2010).

The metropolitan area of Recife, capital of Pernambuco State, and the most populous area of northeastern Brazil, is a well-known route of illegal wildlife trade in the country (RENCTAS, 2001). Residents of Recife can easily indicate well-known sites where animal trade takes place, which are usually located in street markets (Pereira and Brito, 2005). Although this activity is known in the city and trade sites are easily identifiable, initiatives oriented to quantify and qualify this activity in the region are still rare, resulting in a lack of information on the real extent and impact of this practice. Precise data on the wildlife trade, the number of individuals and species involved, and the drivers behind such activity are essential for fighting it, as well as to inform the society and the environmental authorities on the relevance of such activity for the conservation of the biodiversity (TRAFFIC, 2011). Here we use the example of Recife to access the extent and impact street markets may have on biodiversity. We present quantitative and qualitative information on the illegal trade of wild birds in 10 street markets in the area, indicating which species are preferred and why, estimating the number of animals and the volume of money involved, and quantifying the impact that the removal of those animals may have. Our data contribute with the characterization of a highly impacting and widespread activity, but frequently neglected by the environmental authorities, not just in Brazil, but elsewhere.

2. Material and methods

Recife area ($8^{\circ}04'03''S$, $34^{\circ}55'00''W$) comprises 14 municipalities (ca. 2800 km²), with a population of 3.6 million inhabitants and a per capita income of US\$ 6805.77 (IBGE, 2010) (all values here presented were converted from Brazilian real to US dollars, considering US\$ 1.00 = R\$ 1.80, as of mid-September 2011). We visited 10 street markets in the great Recife area: Peixinhos, in Olinda (hereafter M1); Abreu e Lima (M2); Paratibe (M3), in Paulista; Linha do Tiro (M4) in Recife; Cabo de Santo Agostinho (M5); Cavaleiro (M6) and Prazeres (M7), both in Jaboatão dos Guararapes; Cordeiro (M8), Casa Amarela (M9) and Madalena (M10), all in Recife. Site choice was based on previous studies (Pereira and Brito, 2005), and on information obtained from people who pointed out trade sites. The sampled street markets are open on Saturdays or Sundays, starting between 05:00 h and 07:00 h, and lasting for 2–3 h. The exceptions were M4, which takes place twice a week, on Wednesdays (starting at 12:30 h) and Saturdays, and M9 and M10, which are daily. We visited each street market three times, respecting an interval of several weeks between visits. The exception was M6, visited only once, due to safety reasons. All markets attract hundreds of passers-by and one of the authors (R.F.S.R.) acted as a possible normal buyer, without arousing any suspicion from sellers.

In each market, we observed whether there was direct or disguised exposition of wild birds for trade. In each visit, we recorded time of arrival and departure, number of birds exposed, their sex, age and physical condition, prices paid, the common names of the species, and the number of traders. We filmed our visits with

a hidden pen camera (resolution of 640×480 pixels) attached to the shirt collar of the observer, and images were later analyzed in the computer for checking the accuracy of our counting and classifications.

Since we conducted an inventory, we built a collector's curve based on the species accumulated in 22 visits, smoothing the curve with 100 randomizations. Species accumulation curves and parametric and non-parametric estimators can be used to estimate the expected number of species for a given site or sampling (Colwell and Coddington, 1996; Longino and Colwell, 1997; Moreno and Halffter, 2000). We used the program EstimateS 8.2.0 (Colwell, 2006), and selected estimators Chao 1, Chao 2, Abundance Coverage Estimator (ACE), Incidence Coverage Estimator (ICE), Jackknife 1, Jackknife 2, and Bootstrap (Colwell and Coddington, 1996).

We identified the bird species using specialized literature (Sigrist, 2009), or by comparison with digital sources (Wikiaves, 2011), the bird collection of Universidade Federal de Pernambuco, the Centro de Triagem de Animais Silvestres of the Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renováveis (IBAMA), and with the help of specialists (Y. Marinho and R. Rodrigues). To sex birds, whenever possible, we considered the presence of sexual dimorphism, especially color differences between males and females. We used the official Brazilian list of endangered species (IBAMA, 2003) and the IUCN Red List (IUCN, 2011) for assigning each species' conservation status. Both scientific and English common names for the species also followed the IUCN Red List (IUCN, 2011).

We divided individuals into four categories according to their physical condition: (1) not stressed – birds exposed in individual cages, proportional to their sizes, without evident signs of injury or abnormal behavior, such as excessive wing flapping, successive escape attempts, and self-mutilation; (2) stressed – birds confined and grouped in small and limited compartments, with few or no food and water, with different species or males of the same species together, leading to conflicts, or even individuals that exhibited other abnormal behaviors; (3) injured – visually injured birds, with or without signs of bleeding, mutilation or fracture; and (4) dead birds.

We considered the prices of individuals being sold to estimate the size of the local wild bird market. We assumed a scenario in which the same individual did not remain for sale for over a week, based on observations we made that some dealers frequently exhausted their stocks in a single morning. In fact, some of the top sellers do not bring their whole stock to the market and keep several animals in deposits (usually cars and/or houses around the fair), accessing them to replace sold stocks. The determination of the turn-over rate for those animals would be precise just if we had used a marking approach, which is not viable considering the illegal aspect of the activity and the obvious unwillingness from sellers to cooperate with this type of research. We identified the species with the highest and lowest prices and considered the average, minimum, maximum and modal prices for each visit and each street market. We used the sum of those values to estimate the average, minimum and maximum totals potentially handled by each street market in 1 year (52 weeks), as well as to estimate the total volume of money handled in the 10 street markets surveyed. We used Microsoft Access and Excel for data handling and tabulation, and BioEstat 5.0 to test correlations (Ayres et al., 2007).

3. Results

3.1. The markets

We sampled street markets from the last week of August 2010 to the last week of April 2011. Considering 28 visits, we made

1820 min of observation, with an average of 65 min/market. We confirmed the illegal wild bird trade in 22 visits in eight out of 10 markets surveyed. No trade was observed in M9 and M10 and, therefore, they were excluded from our further analysis. We did not notice control or repression of this illegal activity in any visit. M8 had the highest average number of dealers (30/visit), the highest total number of species (42) and individuals (553), M5 the lowest average number of dealers (15/visit), M2 the lowest total number of species (22), and M1 the lowest number of individuals (135) (Table 1; Fig. 1).

3.2. Taxa observed

We observed a total of 2130 birds on sale, which belonged to four orders, 15 families, 34 genera, 55 species and four hybrid forms (Appendix S1, Fig. 2). As it was impossible to taxonomically identify hybrids, and considering they represented less than 0.002% of the sample, these forms were not added to the list of observed species neither included in our analysis. The collector's curve we obtained was close to stabilization (Fig. 3), and the richness estimators we used predicted the occurrence of 61–75 species in the eight street markets. On average, we observed 18 species/market, varying from 12 to 30 (Table 1). Seventeen species were rare: ten were represented by a single individual, and seven by two individuals.

Passeriformes (87% of all species), Psitaciformes (7%), Columbiformes (4%) and Piciformes (2%) were the most frequently observed orders (Fig. 2). The families with the highest number of genera and species were Thraupidae (9 genera; 15 species), Emberizidae (5; 12) and Icteridae (5; 6) (Appendix S1, Fig. 2). Eight out of 15 families were represented in more than 50% of the 22 observations: Emberizidae (22 visits), Thraupidae (22), Turdidae (20),

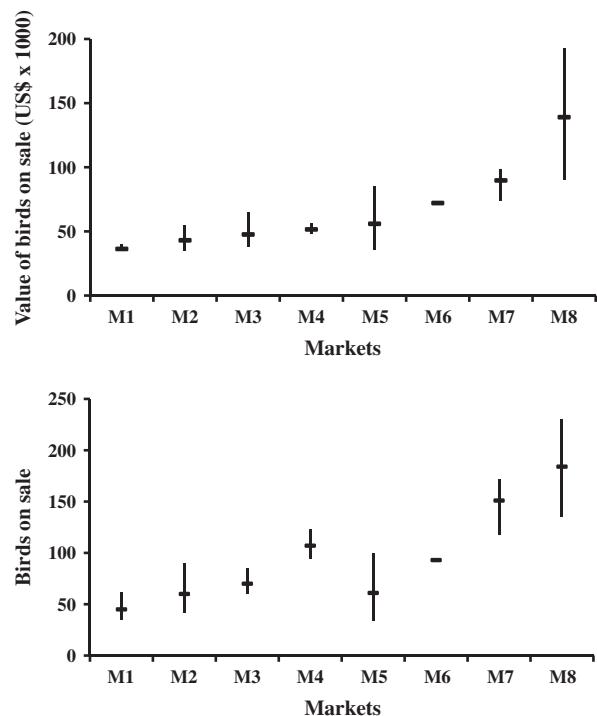


Fig. 1. Minimum, average and maximum number of individuals and total value (in US\$) of wild birds illegally on sale in eight street markets in Recife area, Pernambuco State, Brazil. Each market was surveyed three times between August 2010 and April 2011, with exception of M6, sampled only once. Average, minimum and maximum prices for all the specimens recorded on sale were used to project the total values handled by each market in 1 year (52 weeks).

Table 1
Illegal wild bird trade in eight street markets of Recife area, Northeastern Brazil, with the projection of total number of birds and the volume of money (in US\$) traded in 1 year (52 weeks). All markets were visited three times between August 2010 and April 2011, except M6, visited only once. Minimum and maximum intervals are provided in brackets.

Street market	M1	M2	M3	M4	M5	M6	M7	M8	Total
Name and locality	Peixinho, Olinda	Abreu e Lima, Paulista	Paratibe, Paulista	Linha do Tiro, Recife	Cabo de Santo Agostinho	Cavaleiros, Jaboatão dos Guararapes	Prazeres, Jaboatão dos Guararapes	Cordeiro, Recife	–
Daily frequency/week	1	1	1	2	1	1	1	1	–
Average number of sellers (min.–max.)	19 (16–22)	19 (19–20)	19 (18–21)	21 (20–23)	15 (14–17)	18	29 (24–38)	30 (26–35)	22 (14–38)
Species observed	24	22	24	26	23	19	37	42	56
Average species/visit (min.–max.)	13 (12–15)	13 (10–16)	15 (12–19)	17 (16–19)	14 (12–15)	19	27 (25–28)	26 (24–30)	18 (12–30)
Bird families	9	10	9	8	9	9	9	12	15
Average families/visit (min.–max)	6 (5–6)	6 (6–7)	7 (6–7)	6 (5–7)	6 (5–8)	9	7 (8–9)	8 (6–10)	9 (5–10)
Birds on sale	135	181	210	322	184	93	452	553	2130
Average number of birds on sale/visit (min.–max.)	45 (35–62)	60 (42–90)	70 (60–85)	107 (94–123)	61 (34–100)	93	151 (118–172)	184 (135–230)	97 (35–230)
Average projection of birds on sale/year	2340	3120	3640	11,128	3172	4836	7852	9568	40,352
Average value of birds on sale/visit	660.18	782.59	865.18	936.85	1016.48	1310.00	1630.36	2525.92	1215.94
Total value of birds on sale – Visit 1	627.77	631.67	1171.67	1020.00	850.00	1310.00	1760.55	1638.89	9010.55
Total value of birds on sale – Visit 2	627.77	991.11	737.78	922.22	1546.67	–	1790.55	2440.00	9056.10
Total value of birds on sale – Visit 3	725.00	725.00	686.11	868.33	652.78	–	1340.00	3498.89	8496.11
Lower projected value of market/year	32,644.04	32,846.84	35,677.72	45,153.16	33,944.56	68,120.00	69,680.00	85,222.28	403,288.60
Average projected value of market/year	34,320.00	40,675.44	44,980.00	48,706.84	52,837.77	68,120.00	84,760.00	131,328.60	505,728.65
Higher projected value of market/year	37,700.00	51,537.72	60,926.84	53,040.00	80,426.84	68,120.00	93,108.60	181,942.28	626,802.28

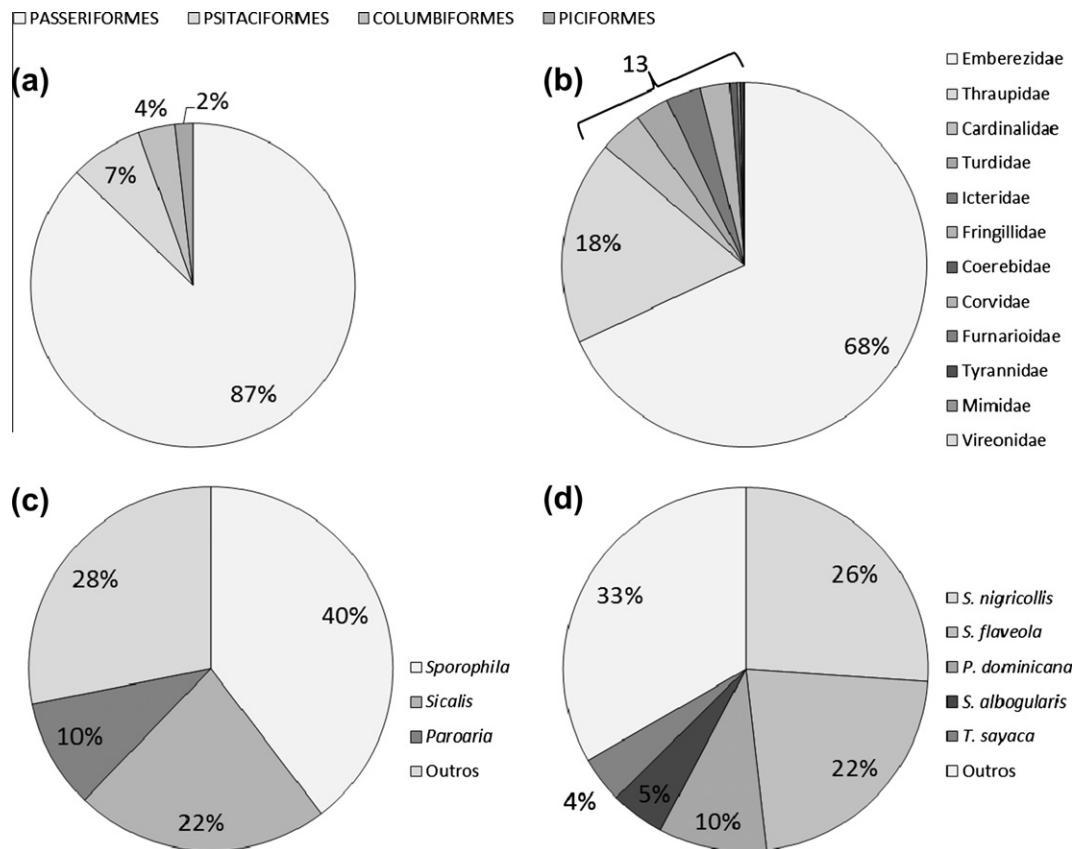


Fig. 2. Distribution of 55 wild bird species illegally on sale in eight street markets in Recife area, Pernambuco State, Brazil, between August 2010 and April 2011. (a) Orders, (b) families, (c) genera, and (d) species.

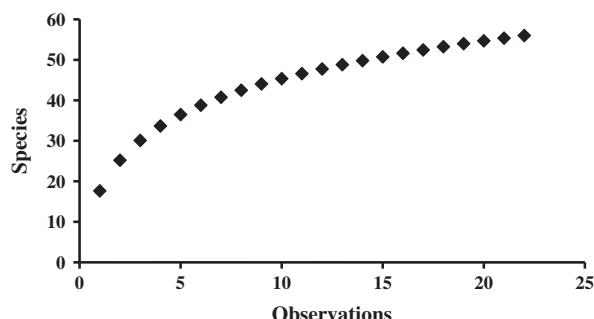


Fig. 3. Bird species accumulation curve based on 22 visits to eight street markets in Recife area, Pernambuco State, Brazil, between August 2010 and April 2011. Fifty-five species were observed and the curve was smoothed with 100 randomizations.

Cardinalidae (20), Fringillidae (15), Psitacidae (13), Icteridae (13) and Coerebidae (11). Passeriformes represented 99% of all individuals (2093 birds). Emberizidae (68%) and Thraupidae (18%) were the most representative families. The other families accounted for 13% (Fig. 2). Considering the total of individuals, *Sporophila* (40%), *Sicalis* (22%) and *Paroaria* (10%) were the most frequent genera; the other genera corresponded to the remaining 28% (Fig. 2). Five species represented 67% of all individuals: yellow-bellied seedeater (*Sporophila nigricollis* – 26%); saffron finch (*Sicalis flaveola* – 22%); red-cowled cardinal (*Paroaria dominicana* – 10%); white-throated seedeater (*Sporophila albogularis* – 5%); and sayaca tanager (*Thraupis sayaca* – 4%).

3.3. Sex and conditions

Adults represented 60% of all individuals (Appendix S1). Twenty-seven species did not exhibit sexual dimorphism related to color, thus preventing us from sexing 553 individuals. Other 831 individuals belonged to species that exhibit dimorphism, but they were mainly juveniles without the characteristics that differentiate males from females. Therefore, it was not possible to identify the sex of 1254 out of the 2130 individuals observed. Among the individuals for which sex identification was possible, males were more abundant (848 birds). We observed signs of stress in 82% of all individuals, injuries in 1%, and only a single dead individual (*S. nigricollis*, in M1). The most common stressors were the confinement of a large number of individuals in small compartments (like up to 30 *S. flaveola* in a 40 cm × 40 cm × 30 cm cage), the maintenance of individuals of different species in a single cage, and improper handling of individuals, with vendors frequently shaking or teasing them. The most common stress sign observed was excessive wing flapping, often leading the animals to exhaustion.

3.4. Origin and conservation status

Out of the 55 bird species recorded, at least three are endemic to northeastern Brazil (*P. dominicana*, *Tangara fastuosa* and *Carduelis yarrellii*), and other three do not naturally occur in Pernambuco (the red crested cardinal, *Paroaria coronata*, Thaupidae; the double-collared seedeater, *Sporophila caerulescens*, Emberizidae; and the hooded siskin, *Carduelis magellanica*, Fringillidae), indicating that some animals are captured very far from the point of sale (e.g. Herrera and Hennessey, 2007; Nijman, 2010). Two observed

species are endangered (the seven-colored tanager, *T. fastuosa*, and the yellow-faced siskin, *C. yarrellii*), and one (*P. coronata*) is in the Appendix II of CITES, which regulates the international trade in endangered species (CITES, 2011). Although rare in our observations (five individuals of *T. fastuosa*, nine of *C. yarrellii*, and two of *P. coronata*), the former two species are listed as vulnerable to extinction both in the Brazilian endangered species list (IBAMA, 2003) and IUCN Red List (IUCN, 2011).

3.5. Number of individuals on sale

The average number of birds on sale per visit varied from 35 (in M1) to 230 individuals (in M8) (Table 1). Considering the 22 visits when illegal bird trade was observed, there were on average 97 individuals/market. Based on the minimum, average and maximum numbers of individuals observed on sale, and considering a scenario where birds stay for sale for no longer than 1 week, we estimate that the eight street markets handle per year an average of 40,352 birds (Table 1). For *S. nigricollis*, the most frequently observed species, we estimate that the eight street markets deals between 5928 and 16,848 individuals annually, with an average of 10,972 birds.

3.6. Prices and trade volume

The most expensive species were the blue-fronted amazon (*Amazona aestiva*, $n = 3$) and the lesser seed-finches (*Oryzoborus angolensis*, $n = 20$), reaching up to US\$ 167.00 per individual (Appendix S1). Prices that high were rare. The lowest values we observed were for the bananaquit (*Coereba flaveola*, $n = 13$) and the pileated finch (*Coryphospingus pileatus*, $n = 17$), with individuals being sold for only US\$ 1.10. *S. flaveola* ($n = 469$), *S. nigricollis* ($n = 554$), and *P. dominicana* ($n = 204$) contributed the most for the total bird worth (Appendix S1).

The total bird worth per visit varied from US\$ 627.77 (in M1) to US\$ 3498.89 (in M8) (Table 1; Fig. 1). Considering the total of visits to a given street market, M1 exhibited the lowest average total value (US\$ 660.18), and M8 the highest (US\$ 2525.55). Considering all street markets together, the average value worth was US\$ 1215.94/visit. Based on a scenario of a 1-week turn rate for all birds on sale, the minimum estimate for total bird trade in 1 year (52 weeks) varied between US\$ 32,644.04 (in M1) and US\$ 85,222.28 (in M8), the average varied between US\$ 34,320.00 and US\$ 131,328.60, and the maximum varied between US\$ 37,700.00 and US\$ 181,942.28. We estimate that the illegal bird trade in the eight markets we sampled worth between US\$ 403,288.60 and US\$ 626,802.28 per year, with an average of US\$ 505,728.65 (Table 1).

There was a negative relationship between price and number of individuals for the most abundant species, except for *S. flaveola* ($r = -0.5278$; $P = 0.011$) and *P. dominicana* ($r = -0.6731$; $P < 0.005$).

4. Discussion

Although considered illegal in Brazil, there is an evident trade of wild birds in the street markets of Recife area. Such trade deals with significant amounts of money (up to nearly US\$ 630,000.00 annually), and has a high and diversified species offer, biased towards adult male songbirds. We estimate that up to 50,000 wild birds may be sold annually in the eight street markets surveyed, including 16,800 individuals of *S. nigricollis*, the most frequently observed species. There are no precise data on the number of death animals associated with the wildlife trade, but taking a conservative estimate that three animals die for each one traded (see Redford, 1992), up to nearly 67,000 individuals of this species

may be removed from nature each year to supply the eight markets surveyed. Those values indicate that street markets are wildlife sinks, with a large and frequently ignored impact on the regional biodiversity that must be taken into account in the control and conservation of biodiversity, not just in Brazil but elsewhere. The impact of such sites on the removal of live animals from nature to supply both pet markets as well as traditional medicine and the bushmeat market cannot be ignored (e.g. Alves and Rosa, 2010; Fernandes-Ferreira et al., 2011; Kamins et al., 2011; Lyons and Natusch, 2011).

Like in any illegal activity, it is difficult to measure the actual numbers related to illegal wildlife trade (Barber-Meyer 2010). Estimates point out that four million wild animals are probably destined to the illegal trade annually in Brazil (RENTAS, 2001). However, those statistics are usually stated without the supporting data, therefore lacking a scientific basis. The combination of data here presented with those from a previous study (Pereira and Brito, 2005, obtained along a 5-year survey) indicates that at least 109 wild bird species are sold in the street markets of Recife area. Data on fauna seizure in other regions of Brazil also indicate a varied offer of bird species for trade: 93 species of 26 families in Rio Grande do Sul State between 1998 and 2000 (Ferreira and Glock, 2004); 48 species of 17 families between 1993 and 1998 in southeastern Bahia State (Souza and Soares-Filho, 2005); 98 species between 2006 and 2007 in Paraíba State (Pagano et al., 2009); in Minas Gerais State, 30 species in Montes Claros in 2007 (Campedelli et al., 2009), and 78 species of 25 families between 2002 and 2004 in Juiz de Fora (Gogliath et al., 2010). Together, those scattered data can give an idea of the number of species removed from nature to supply the illegal bird trade in Brazil.

Sources quantifying illegal wildlife trade in other countries are also scarce. Nash (1994) concluded that domestic trade in live songbirds within Indonesia roughly removes at least 1.3 million wild-caught birds per year. In Santa Cruz de La Sierra, Bolivia, a study on the trade of psittacines in street markets in the region recorded 7279 individuals in 1 year, projecting a market of ca. 22,000 parrots/year (Herrera and Hennessey, 2007). Data on the legal exportation of wild animals in Southeast Asia between 1998 and 2007 indicate that 30 million specimens have been removed from nature (Nijman, 2010), and out of the tens of millions of reptiles and amphibians imported annually between 1998 and 2002 by the USA, at least 2.5 million individuals were captured directly from nature and entered the country illegally (Schlaepfer et al., 2005). The removal of such a high number of individuals from nature can lead, in the medium- and long-term, to species extinctions (e.g. Wright et al., 2001), and compromise several ecological services, such as pollination, seed dispersal, and control of populations of other animals (e.g. Muller-Landau, 2007; Stoner et al., 2007).

Values along commodity chains in the illegal wildlife trade routinely increases by at least one order of magnitude, proving that the activity is highly profitable. Global estimates vary widely, from US\$ 6 to 20 billion/year for the whole illegal wildlife market (Wylde and Sheikh, 2008; TRAFFIC, 2011). Like in any illegal activity, profits are not included in the formal economy of the countries. Furthermore, environmental facilities designated to receive seized animals – when existing – are frequently overloaded, with animals being processed in inappropriate conditions, resulting in a loss of scientific information and knowledge.

Some of the species that stand out in illegal trade are already endangered, whereas the most abundant species are frequently neglected in studies on the impact of the removal of individuals from natural populations (Schlaepfer et al., 2005; Shepherd and Nijman, 2008; Nijman, 2010). Studies on this topic in Brazil are essential for a better characterization of the conservation problem represented by illegal wildlife trade (Olmos et al., 2005). The top three species

on sale in our survey were, respectively, *S. nigricollis*, *S. flaveola* and *P. dominicana*. The last two were always among the top-three traded and seized species in other parts of Brazil (Ferreira and Glock, 2004; Souza and Soares-Filho, 2005; Campedelli et al., 2009; Pagano et al., 2009; Gogliath et al., 2010). In spite of that, none of them are considered endangered in the country. Our ranking of species on sale differs from the one obtained in the same area, between 2000 and 2005, by Pereira and Brito (2005): *P. dominicana*, *S. albogularis* (White-throated Seedeater) and *S. nigricollis*, respectively. The change from 2000 to 2011 may indicate that at least the offer of *P. dominicana* has been decreasing in the past decade. Such change may be explained by (a) a decline in the offer of this species in nature, (b) a decline in the demand for this species, or (c) environmental control forces that are preventing those animals from reaching the markets. Since we have no information on any increase of the illegal trade control, the first hypothesis seems plausible, indicating that *P. dominicana* may be undergoing a decline in nature. However, this hypothesis must be investigated. The species, endemic to the Brazilian Caatinga (a dry forest in the Northeastern of the country), is targeted by poachers in this region and may be undergoing a situation similar to that of *S. flaveola*, the chopi blackbird (*Gnorimopsar chopi*), and of larger psittacines that went nearly extinct in the region due to illegal poaching and trade (Olmos et al., 2005).

4.1. Motivations for illegal trade

The demand for songbirds is the main driver for the illegal wild bird trade in the street markets in Recife, and other areas in Brazil as well (see Fernandes-Ferreira et al., 2011). Contrary to our expectations, rare or endangered species were not necessarily the most expensive in our surveys. The price of a bird is determined by a combination of its physical appearance, and the beauty, shape and melody of its song. Indeed, *S. flaveola* and *O. angolensis*, both with high potential of melodic and sequential singing, reach higher prices when in good condition. The presence of psittacines, which are much appreciated both nationally and internationally, was relatively low in the street markets we surveyed. Such birds are listed in the Appendices of CITES (2011), what increases the repression of their illegal trade compared to other groups (Herrera and Hennessey, 2007). The fine imposed for people selling those birds in Brazil varies from US\$ 278.00 to US\$ 2780.00, according to whether the species is threatened or not (Brasil, 1999). Hence, the exposition of those animals in street markets is less evident, and their illegal sale is frequently made by order.

Most animals on sale showed evident signs of stress and the few in good conditions had probably passed through an acclimatization period or were identified by sellers as having higher potential value, receiving better care. The confining of many individuals of same or different species in small compartments frequently results in fights, with injuries and possibly death. However, sellers reported that dead animals are immediately discarded, since their presence in the cages is bad for business. Therefore, buyers rarely perceive that several animals die during the trade, and may lack the real understanding of the environmental damage it causes, the scale of such market, the high profits and criminal elements involved.

Black markets are driven by supply and demand of a product, the objectives and efficiency of the controller and those controlled, and the method of implementation of exchange of goods (Brack and Hayman, 2002). In the case of wildlife trade, complex rural to urban supply networks are developed and driven by urban demand (see Broad et al., 2003). We observed that buyers in the street markets of Recife area are average citizen (fathers and boyfriends presenting their sons and lovers) plus professional songbird breeders looking for matrices. Therefore, in addition to monitoring

and enforcement initiatives by state and federal environmental agencies, conservation initiatives to reduce the impact of illegal wildlife trade will have, invariably, to address such people, at risk of failing in its objectives.

We observed that sellers do not seem to worry about the possibility of inspection and punishment. Their biggest concern is losing their "goods", which shows the inefficiency of the local law enforcement and the absence of punishment to offenders. Sellers have multiple ways to escape inspection: the trade is usually done early in the morning because inspections, when executed, usually arrive late, giving enough time for profit and reducing the loss of animals by apprehension. In extreme situations, sellers simply abandon animals on site and mix with the crowd to escape the act. The absence of constant and active repression and the feeling of impunity encourage offenders to stay in this business.

The values presented here can and must be refined, but they represent an alert on the magnitude of the impact street markets dealing with wildlife have on biodiversity. Such sites are real biodiversity sinks and both society and authorities are underestimating the mid and long-term damage those sites are causing. Illegal wildlife trade is well-known in Brazil and elsewhere: everybody, including authorities, knows where to find it, the subject is covered by the media, and part of the people is aware on the negative impacts associated with such activity. However, measuring properly the number of animals involved still is a difficult and challenging task. Science can contribute by producing and refining the necessary data to assess the real impact of illegal wildlife trade. But research alone will not be able to fight it. Illegal wildlife trade must be faced as an environmental, economic and social problem.

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Appendix A. Supplementary material

A list of the species we recorded, their respective number of males and females and prices paid (Appendix S1) is available online. Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2012.02.009.

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