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Review

Natural recolonization and suburban presence of pumas (*Puma concolor*) in Brazil

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The puma (*Puma concolor*, Carnivora: Felidae), extinct from considerable extensions of its former distribution, is considered threatened in south, southeast and northeast Brazil. Areas in the south and southeast have only recently been recolonized by the species, following decrease in logging activities after depletion of the Atlantic rainforest in the 1960s, and measures implemented since 1993 to protect this ecosystem. Data on recovery of puma populations was obtained from field observations based on the onset of depredation on sheep flocks in 1988, and also from the presence and growing number of records of pumas in urban and suburban areas since 2004. Logging bans caused a rural exodus since and also a 15 fold drop in the deforestation rate, creating conditions for a partial recovery of wildlife. Thirty-five records of puma were compiled demonstrating the historical presence of the species in the area prior to its temporary absence. Recent records included twenty-four cases in urban and suburban areas, and eleven of current breeding populations.

Key words: Araucaria forest, Atlantic forest, deforestation, *Puma concolor*, recolonization, recovery.

INTRODUCTION

The cases of natural recolonization in populations of large-bodied wild felids across large spatial scales are scarce in literature, as large felids are more prone to decline than to recover given the global and widespread loss of habitat integrity and direct persecution due to livestock depredation. If happening, recolonization is often limited to single locations (Harihar et al., 2011), or have been accomplished through reintroduction, some successfull others not (Breitenmoser et al., 2001; Hayward et al., 2007; Jule et al., 2008; Slotow and Hunter, 2009). Dramatic, country-wide changes in human attitude towards large cats, and hence on management in practice (either formal or informal) that could translate into population recovery, are not common. This is observed by the world-wide decline in the range of jaguars (*Panthera onca*), leopards (*Panthera pardus*), lions (*Panthera leo*), tigers (*Panthera tigris*) and cheetah (*Acinonyx jubatus*) (Nowell, 2009). In Brazil, as in the remaining of South America, lack of wide-scale data on distribution of pumas (*Puma concolor*) has prevented precise assessment of their population status (Laundré and Hernandéz, 2010). It is thus meaningfull that available information on distribution and status of puma be better organised to fulfill this gap in our current knowledge of the species. Such data will be unfolded here for the south (S) and southeast (SE) regions of Brazil, based on both historical and field data of the species and its habitat, while the recolonization patterns of pumas in this regions are also unwrapped.

The puma is considered endangered in the northeast, south and southeast regions of Brazil (Machado et al., 2008), having in fact lost considerable extensions of its former range in areas of higher human density, such as the eastern coast of Brazil (encompassing the easternmost areas of the mentioned regions). The puma is, however, far from being rare or uncommon in both S and SE regions of Brazil, where the listing of pumas as endangered in S and SE Brazil arises a suspition that its declared status is more of a result of a precautionary approach than the imminence of their extinction; perhaps a necessary precaution given the expressive decline undergone by the species in the past decades, as argued herein. Currently, however, the range of puma in Brazil is very broad, encompassing preserved terrestrial ecosystems (both in private and public lands) throughout the five regions of the country, widespread and often recorded in the areas where it is considered endangered; south (Azevedo, 2008; De Angelo et al., 2011; Mazzolli, 1993, 2006, 2010; Mazzolli and Hammer, 2008; Pitman and Galvão, 2002; Vidolin et al., 2004) and southeast (Chiarello, 1999; Lyra-Jorge et al., 2009; Martins et al., 2008; Miotto et al., 2011).

Herein, the evidence of the retraction of range and posterior recolonization of pumas in S and SE regions of Brazil, over an area of 1,500,000 km^2 was described. These results represent data from the only known recolonization event of a large wild felid in Brazil, which is also one of a few in the world. Its recolonization is likely a result of the cessation of uncontrolled logging in the Atlantic forest ecosystem, which currently enjoys a higher level of protection than any other continental ecosystem in Brazil. Although available in the literature, data with information relevant to describing puma recolonization in S and SE Brazil have not been summarized so far and links between findings are incomplete to provide the whole scenario. This work, therefore, reviews the available information on puma status and recolonization in Brazil, setting the stage to argue, based on novel evidence, that the growing number of records of pumas in urban and suburban areas are an extension of the recolonizaton processs and range expansion in the country.

Study area

Climate and vegetation is not uniform throughout south (S) and southeast (SE) regions of Brazil. They all are, however, humid, with precipitation usually falling between the 1,200 to 2,000 mm range. Evergreen forest predominte by sea level, low altitudes, and coast mountains (such as Serra do Mar mountain range), displaying a westward transition to an ecosystem adapted to a cooler climate, consisting of coniferous forests intermingled with montane grasslands in the Tablelands, at altitudes prevailing between 900 to 1300 m. Continuing westward, a semideciduous forest predominate. A latitudinal gradient of the habitats is also observed, with greater extensions of montane grasslands and coniferous forest in the south, and larger extensions of seasonal and of open and woodland savanna (known as Cerrado) to the north.

The Atlantic forest, highly regarded as one of the top global hotpspots of biodiversity and endemism (Myers et al., 2000), and one of the most threatened biomes in the world (Dinerstein et al., 1995), is in fact a mosaic of ecosystems that encompass most of the land area and vegetation as aforementioned, except for the extreme southern montane grasslands (Pampa) and the northern Cerrado. It also includes coastal vegetation such as scrubland, it is distributed in a land strip in the northeastern region, extending southward to encompass most of the land area of S and SE regions. The Tablelands in the State of Santa Catarina (S Brazil) is the place where most of the direct information on recolonization of pumas was collected. It is dominated by the Araucaria Moist Forest, named after the dominat arboreal species, the *Araucaria angustifolia*, and considered an ecoregion of the Atlantic Forest (Dinerstein et al., 1995; WWF, 2001). Mean annual air temperatures range from 10 to 16°C (SEPLAN, 1991), in winter frequently reaching frosting conditions and in the colder days decreasing to minus 10°C. Altitudes range from 800 - 1800 m and the climate is mesothermic humid in most of the region, with rainfall varying from 1,400 to 2,000 mm per annum (SEPLAN, 1991).

METHODOLOGY

Past records of puma during the presumpted period of declilne were obtained from museums (Mazzolli, 1992). Latter evidence were mainly skins and trophies obtained from ranchers and also depredation incidents (Mazzolli et al., 2002). To record the recolonization of pumas in the tablelands, ranches without historical records of losses to pumas were revisited in 2004-2005 to document recent depredation events (Mazzolli, 2006). The growing number of recent records of pumas in urban and suburban areas, were also considered evidence of recolonization by pumas. These were obtained from the author's personal handling of pumas captured or killed, and by records obtained from the news media, through internet search. Key words to retrieve information on pumas occurrence in urban and suburban areas were: the names of puma in portuguese (onça, suçuarana) combined with words in Portuguese for 'town' and 'urban', and names of south and southeast States (south: Rio Grande do Sul - RG; Santa Catarina - SC; Paraná - PR; southeast: São Paulo - SP, Rio de Janeiro - RJ; Espírito Santo - ES; Minas Gerais - MG). Key words used to retrieve information of locations with presence of wild young pumas(to record current breeding populations) were 'young' and the names of puma, all in Portuguese. The retrieved reports were double-checked with additional searches, and used only if also available from known (and hence more reliable) sources, usually national media such as O Globo (2001), Globo (2009, 2010ª, b, 2011), Estadão, Folha (2011), etc, thus avoiding reliance on personnal blogs or sites.

Additional searches were also often needed to obtain information of exact locations and street names. Locations were then searched in Google Earth (Google, Mountain View) using the name of streets or locality for aproximate coordinates in degree, minutes and seconds. A couple of times it was necessary to use Google maps instead, to identify the exact street location. Point locations in Google Earth were exported in KML format to be imported into TrackMaker (Geo Studio Tech., Belo Horizonte) containing a background map of Brazil. The file was then received final edition in Photoshop (Adobe, San Jose) and saved as JPG file. Field evidence of puma decline is given only for the Tablelands of Santa Catarina, whereas evidence of habitat empoverishment that may have driven decline, plus recolonization information by means of increased records, is given at a wider scale.

RESULTS AND DISCUSSION

Known cases of puma recolonization

In spite of few examples of natural recolonization of wild felids world-wide, cases of puma recolonization in the Americas have been reported and are briefly revised here. Unlike reintroductions, which are experimental and have reintroduced individuals geographically circunscribed to a known location, individuals in natural recolonizations are scattered over a large landscape and may not represent a breeding population (lone dispersers). Knowledge of natural recolonizations have often relied on fragmented and oportunistic information, such that many of the reports on this phenomena are not explicitly addressed in publications, but are a subset of information included on a broader report.

Enough evidence has been recently collected to support that the species is recolonizing the Midwest United States (LaRue et al., 2012). Pumas were considered absent from the Black Hills of South Dakota and Wyoming in Midwest United States from 1906 to 1930 (Anderson et al., 2004; Beier, 2010), and have increased in numbers enough to disperse long distances into presumed vacant ranges (Thompson and Jenks, 2005), with at least one new founding population recorded in the Badlands, North Dakota (NDGFD, 2007;Thompson et al., 2009; Thompson and Jenks, 2010). Puma is also believed to be recolonizing eastern United States (Hornocker and Negri, 2010; Pierce and Bleich, 2003; Thompson and Jenks, 2010), and moving east in Canada (Anderson Jr. et al., 2010). Records of puma in eastern US have, however, and regardless of the increasing number of public claims, have been considered inconsistent for lack of 'concrete physical evidence' (McCollough, 2011). Based on the lake of this evidence, the eastern subspecies of puma has been considered extinct and will likely be delisted from the Endangered Species Act (ESA) (McCollough, 2011). The decline of the eastern puma resulted from an early eradication police in the US that counted with official support and bounty payment (Nesslage et al., 2006). In Arizona, for example, on average 328 pumas were hunted annually as a pest for 51 consecutive years (from 1918 to 1969). In this State, pumas were also hunted from 1971 to 1987 as a game animal at an average rate of 235 per year (Smith, 1989), a harvest rate that has been stabilized and maintained (Day Jr, 2011). A wide scale recolonization of the species may be expected in the US due to changes in the species' protection status. In fact, and despite the fate of the eastern puma, dispersing individuals are already reaching Wisconsin and Michigan, and one (confimed by DNA analysis) dispersed as far as Connecticut, located by the Atlantic Ocean (Cat News, 2011; DEEP, 2011; Wisconsin Department of Natural Resources, 2011). Uncontested evidence of established populations at the wider scale are still lacking.

There is also evidence of puma recolonization in Uruguay and Patagonia, but information is fragmented, inadequate to provide a full understanding of the extent and intensity of these events. Recent records of pumas have been reported from Uruguay (Martínez et al., 2010), a country in which pumas were generally considered extinct. These reports may well be of persisting individuals from a once wide-ranging population, as the species is far from having radically changed its previous (uncommon and rare) status. Pumas in this country have unquestionably declined to near extinction, but isolated reports of single individuals had been available from time to time since long (Ximenez, 1972). Further, the species is rarely reported and is considered highly endangered (Martínez et al., 2010), thus not characterizing any substantial increase in numbers and in founding populations so far. Patagonian pumas are reported to have reduced their range in the past and would be currently occupying vacant range, following a decline in sheep business and associated reduction of rural human population (Walker and Novaro, 2010).

The most well documented case of population recolonization and expantion of the puma in the Americas is that of the Florida panther (*P. concolor coryi*). The recovery of the Florida panther perhaps better illustrates what would be necessary for recovery of most of the world's threatened populations of large cats. It required intensive management intervention and population monitoring that extended for decades (United States Fish and Wildlife Service, 2006), culminating in the introduction of new DNA (through transfer of embryos) from a neighbouring puma population in Texas to relieve the inbreeding depression (Johnson et al., 2010). In spite of the apparent recovery, the core habitat of the Florida panther is currently restricted to 9,190 square kilometers (Kautz et al., 2006), fewer than 100 individuals remain in the wild, and their future is uncertain (Gross, 2005).

Drivers of puma decline and recovery in the study area

The precise period in which pumas went extinct in the tablelands is difficult to ascertain from direct evidence, mainly due to the widespread lack of wildlife monitoring in Brazil during the time when it must have happened. It is known that the jaguar (*P. onca*), a sympatric predator of the puma, was last recorded (shot) in the tablelands by 1970, and since then its disappearance wave spread over the adjoining areas (Mazzolli, 2009). Unlike the jaguar, currently with vestigial populations in S and SE Brazil, pumas resisted, but it is not unlikely that the same pressure that caused jaguar retreat during this period may also have caused puma to decline in numbers.

Indirect evidence of the environmental impoverishment and overexploitation of the Atlantic forest that may have caused pumas and jaguars to decline are available. Large tracts of land had timber overexploited by the 1950s-1960s in SE (Dean, 1995) and by 1960s-1970s in the S (Thomé, 1995). In 1850, the State of São Paulo had 80% of its territory covered by forests, and in 1950 the forest had reduced to 18% (Rocha and Costa, 1998). In the tablelands of Santa Catarina, timber became scarce during the 1960s-1970s and a major economic crisis surfaced (Thomé, 1995). Besides the direct empoverishment of habitat, uncontrolled logging may have created conditions to an increase in hunting of wildlife in remote areas during logging peaks. As timber became scarce, villages were settled in remote and wild regions in search of new logging grounds, resulting that the environmental impact of logging was magnified by its association with human colonization. Local settlers, partially isolated from contact from food suppliers, certainly had to supplement their diet with wildlife and

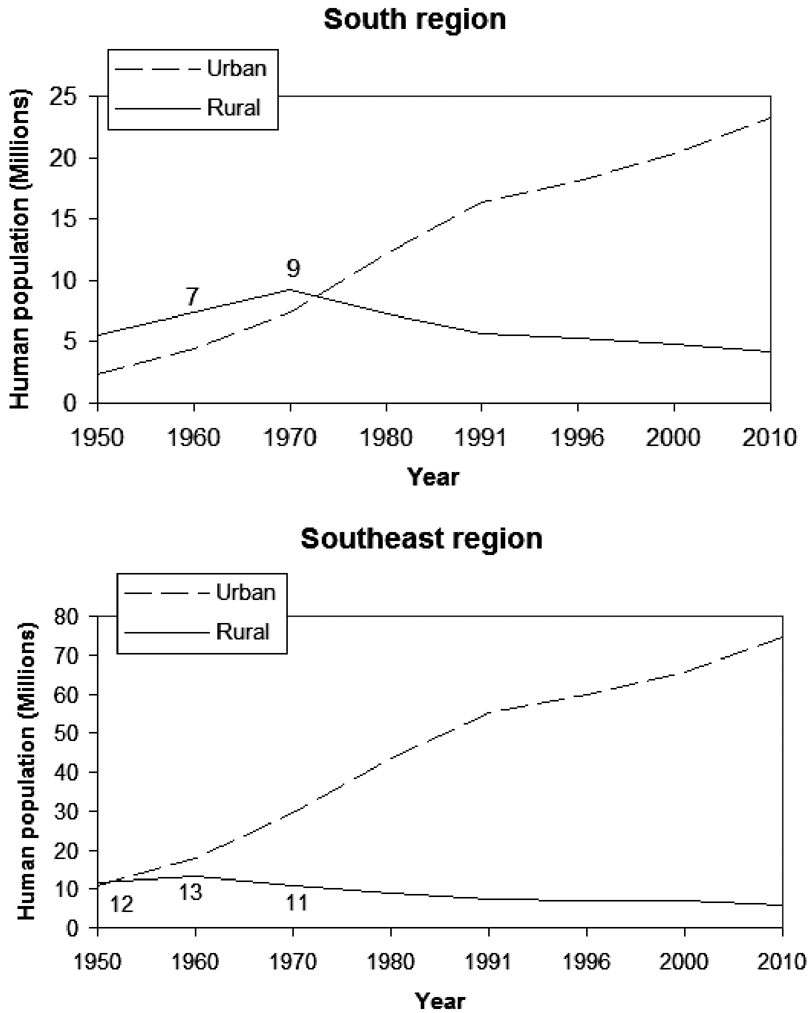

Figure 1. Human population demography in rural and urban areas from 1950 to 2010, showing peaks in rural areas during the 1960s (SE) and 1970s (S), corresponding with logging peaks in each region.

protect their livestock against predators. Poaching by itself is enough to cause substantial impact on wildlife populatons (Peres, 1996; Bennett and Robinson, 2000; Cullen Jr. et al., 2000, 2001), and certainly is magnified when coupled with deforestation. Pumas are still illegally shot nowadays in the S and SE regions of Brazil (Mazzolli et al., 2002), the fact that they still persist may be explained by the absence of saw mills and its associated villages in remote places as before, and due to a steep decline in deforestation rates.

Once timber harvesting declined due to overexploitation, logging areas were abandoned, resulting in a rural exodus in the S and SE regions (Figure 1). The depletion of the most commercially valuable native timber by the 1960s and 1970s caused a slump in the overall exploitation of the forest. Some logging companies moved to the northern yet forested regions of Brazil and the others began to invest in forest plantations. That period of transformation brought a relief in forest exploitation that might have marked the beginning of the environmental recovery process that may have allowed pumas to expand to the areas they formerly occupied. About twenty years after the timber industry breakdown, a couple of other situations resulted in farther improvement of habitat conditions in S and SE Brazil. The first situation was the new and restrictive law of environmental crimes No. 9.605 issued in 1998, followed by a political enforcement to cohibit poaching through the Environmental Police.

The second situation was the release, on 10 February 1993, of the federal decree No. 750, granting full protection status to the Atlantic rainforest. At that time logging had declined but not stopped, and land was still freely cleared for plantations and for firewood. This document provoked a large commotion among those companies that harvested timber, manufactured furniture, produced charcoal, and used firewood to bake tiles, ceramics and bricks. The situation pushed these

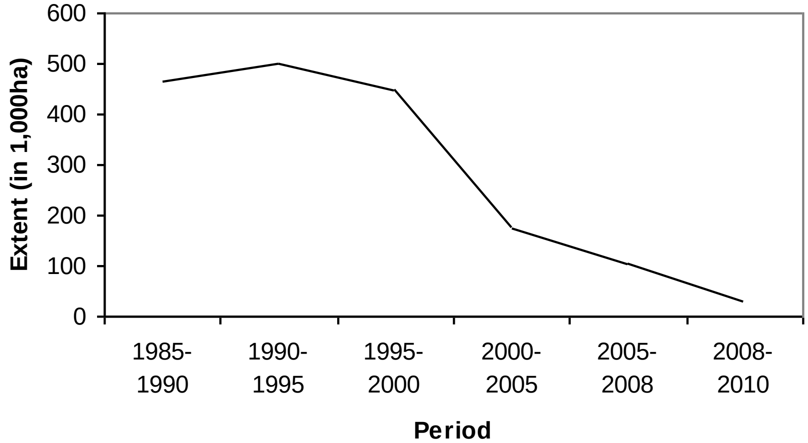

Figure 2. Line chart showing the decline in the rate of deforestation from 1985 to 2010, in hectares, for the entire Atlantic Forest. Data in Table 1 (appendix) (SOS Mata Atlântica, 2011a). See also data in Table 2 detailing deforestation rates for each State of the south and southeast regions (period 1995-2010) (SOS Mata Atlântica, 2003, 2009, 2011b).

companies to find alternative energy and timber sources and this, coupled with the depletion of the Atlantic Forest, pushed a large-scale development of plantation of fast-growing exotic trees. The growth of forest plantations is illustrated by an increase in participation of exotic trees in the national round wood production, from 26,8% in 1990 to 65% in 2006, with the largest share from the S and SE regions of Brazil (Bacha, 2008). The decline of available hardwood and then the prohibition of logging have released much of the pressure on the forest, reducing drastically the rate of deforestation (Figure 2) Prey populations are believed to have also shown signs of recovery after deforestation rates declined. Information is, however, scarce and largely non peer-reviewed. Much like the monitoring of pumas, counts of ungulates and other prey are just unavailable. Instead, the information on the increase in prey species are mentioned by field scientists as accounts (e.g. capybaras: Bellato et al., 2009; Dotta and Verdade, 2011), and are also divulged by the news media. It is important to mention that pumas in the neotropics prey on a large variety of species (Chinchilla, 1997; Emmons, 1987; Monroy-Vilchis et al., 2009), some of which should thrieve in secondary forests and/or modified landscapes once hunting pressure is released, particularly the nine-banded armadillo (*Dasypus novemcinctus*), capybara (*Hydrochaeris hydrochaeris*) and gray brocket deer (*Mazama gouazoubira*). According to the report of Parry et al. (2007), secondary forests appear to support mammal abundances comparable with those of primary forest. In North America (e.g. Ackerman et al., 1984; Leopold and Krausman, 1986; Robinette et al., 1959) and Patagonia (Iriarte et al., 1991), the bulk of pumas often rely on few species. A broader prey choice in Neotropical regions enables the predator to shift to alternative prey when one of the major species suffers a significant decline in numbers. In S Brazil, it was found that armadillos, a highly prolific species, may account for most of the biomass consumed (Mazzolli, 2000; Pitman and Galvão, 2002).

Historical records of puma in the study area

Pumas from S and SE Brazil were long known to naturalists even before their reappearence and recovery. Linneus (1771) had assigned Brazil as type locality of *P. concolor*, based on a skull from the SE region (Nelson and Goldman, 1929), apparently sent by Ihering, a naturalist that had also recorded pumas in S Brazil (Ihering, 1892). Goldman (1946) changed the type locality of puma to French Guiana and so far it has been maintained as such, which according to Hershkovits (1949) was based on an erroneous assumption (Mazzolli and Ryan, 1997). More recently, specimens from the museums 'Museu Nacional do Rio de Janeiro-RJ (MNRJ)', 'Museu de Zoologia da USP-SP (MZUSP)', 'Museu Homem do Sambaqui-SC (MHS), and 'Universidade Federal de Santa Catarina-SC (UFSC)' also demonstrates that pumas persisted in S and SE Brazil during the most critical period of logging and habitat deforestation, from 1960 to 1970 (Mazzolli, 1992) (Figure 3). Most of the specimens deposited at UFSC were collected by the author during field trips (Mazzolli, 1992; Mazzolli et al., 2002).

Direct evidence of puma recolonization collected in S Brazil

The first modern study on the ecology of pumas in Brazil was delivered from investigations carried out in the

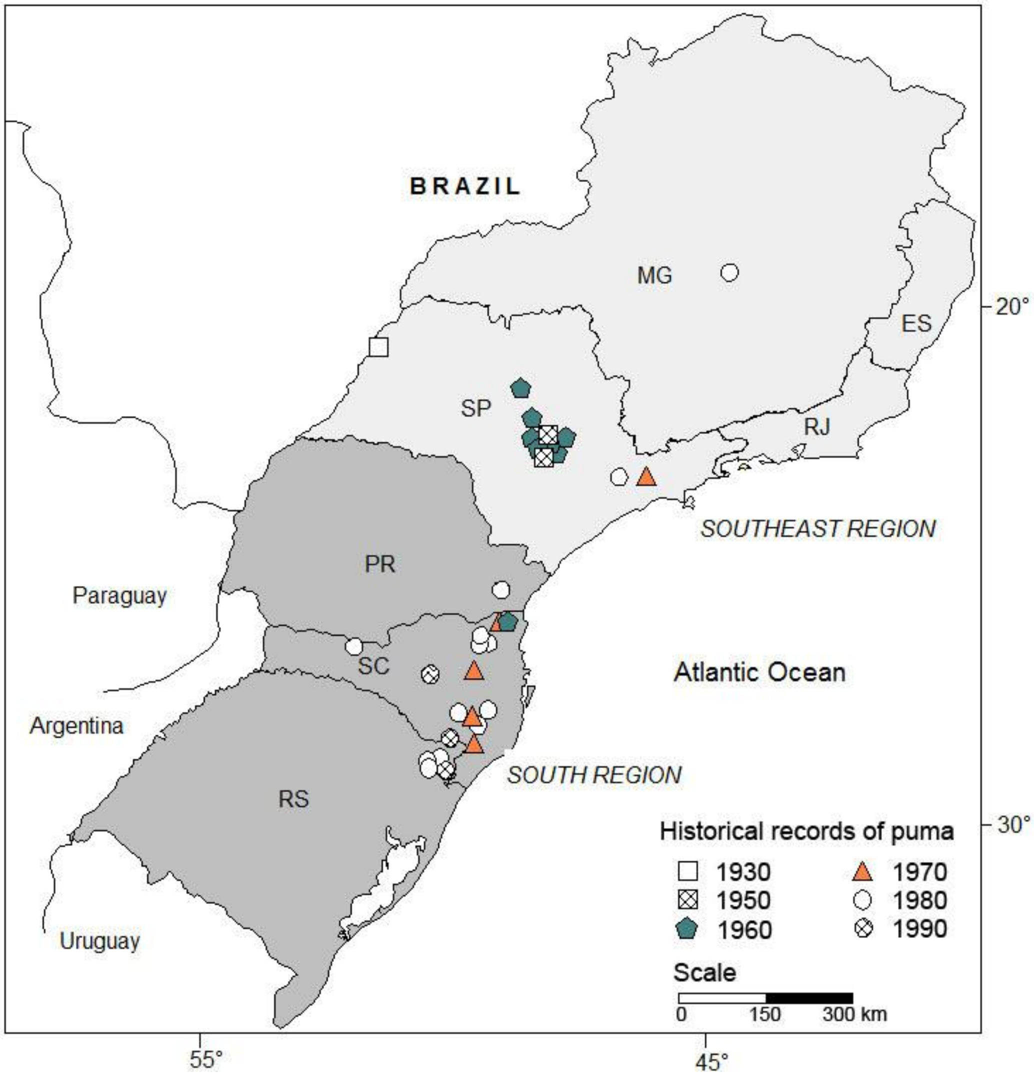

Figure 3. Historical records of pumas from 1930s to early 1990s in south and southeast Brazil. Collored symbols represent the critical period between 1960's and 1970's, period in which pumas may have declined as result of forest overexploitation. Data from Table 3 (appendix).

Brazilian midlle-west region, in the pantanal, designed to obtain information on jaguars (e.g. Crawshaw and Quigley, 1984; Schaller, 1983). Studies in the S region began soon after, when claims of livestock depredation begun to arrive at environmental agencies' desk, concomitantly in the States of Santa Catarina (Mazzolli and Da-Ré, 1988) and Paraná (Vidolin et al., 2004). In Santa Catarina (SC), pumas were often not considered as a native species by ranchers at the time. Ranchers, instead, perceived that either a predator had escaped a zoo or circus, or, soon after learning that our survey had a conservation bias, that the environmental agency was releasing (introducing) pumas in the wild. Interestingly, recolonizing pumas were also considered exotic species by locals in the neighbour State of Rio Grande do Sul (Marques and Ramos, 2003), and as far as Patagonia (Walker and Novaro, 2010). Rancher's were not aware of the puma presence until then, and this was the first indication that pumas had been wiped out and were recolonizing the area.

The survey in SC resulted in the first landscape study of the puma in Brazil, covering an area of four latitudinal by four longitudial degrees. Layers with hypsometric and vegetation maps, superimposed with puma records in 22 locations demonstrated that pumas were ranging mostly in pristine, mountaineous habitats (Mazzolli, 1993). The survey had begun in 1988 and extended up to 1995, resulting in the collection of 20 samples including skulls and pelts from ranchers that kept them as trophies (Mazzolli and Ryan, 1997; Mazzolli et al., 1997; Mazzolli et al., 2002). Pumas shot while attacking livestock, consisted of males, females, adult, subadults, and young. Latter, a larger sample of 37 skin samples from wild pumas poached after depredation was obtained by Castilho et al. (2011) during the period of 2005-2008.

Much has been learned on patterns of puma predation

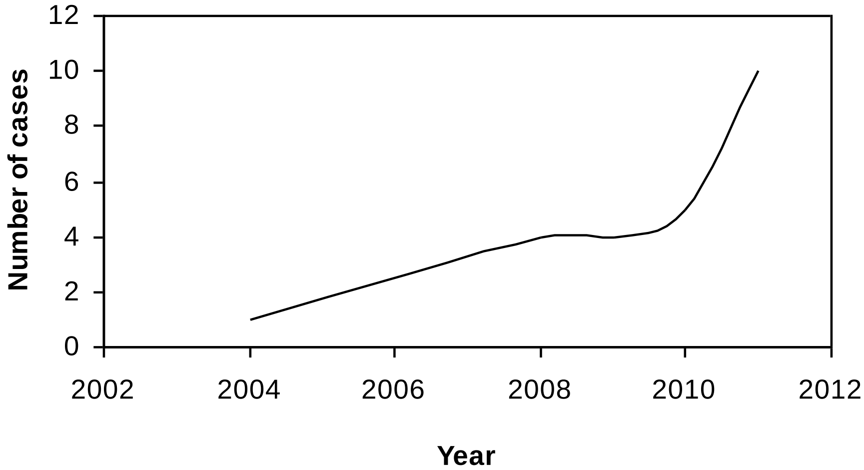

Figure 4. Increase in the number of pumas recorded in urban and suburban areas of south and southeast regions of Brasil. Details on Table 4 (appendix).

on livestock from the studies in SC. Sheep flocks were the most abundant vulnerable livestock, and were prior to puma recolonization, raised free-ranging, with only two out of twelve surveyed ranches having them corraled at night (Mazzolli et al., 1997). From that time onwards, ranches in the S region of Brazil weren't able to keep free-ranging sheep flocks in puma country any longer, as this would imply on depredation almost in a daily basis (Mazzolli et al., 2002). It has been estimated that this predator was responsible for the reduction of 70% of all sheep numbers in S Brazil, at least in the State of Santa Catarina (Mazzolli, 2005), forcing the purchase of sheep from extreme south Brazil (pampas grasslands) and from Uruguay to supply the meat market. The reduction in sheep flocks may be best explained by the unwillingness or inability of ranchers to keep large herds in fenced and safe areas rather than a direct product of depredation. As a result, ranchers simply reduced their herds to make them easily manageable during daytime grazing and nightime keeping in small corrals. Free-ranging sheep in puma country turned unproductive due to the high number of losses compared to those flocks which were kept at nights in corrals (Mazzolli et al., 2002). It is thus assumed here that the early lack of ranchers' awareness of the presence of pumas, and lack of attacks to free - ranging sheep flocks that populated the landscape (Mazzolli et al., 1997) represent sufficient evidence of puma population reduction or absence before the recolonization process.

Furthermore, it is acknowledged that lack of depredation does not always mean that the predator is absent. Attacks by pumas are not uniformly distributed in a given area, and heterogeneity in spatial distribution of depredation may reach extremes exemplified by an entire flock being destroyed in few weeks, while neighbouring flocks are left unmolested for the duration of several years, as observed during the field studies mentioned above. However, it is also acknowledged that attacks will inevitably occur when flocks are available in large numbers across a wide landscape in puma country –and this is a main assumption – it implies that the absence of attacks indicate the absence of pumas, at least in the 'sheep-dominated landscape'. This assumption is supported by the behaviour of pumas in the tablelands of S Brazil. Free-ranging sheep was predated at almost daily basis, whereas attacks to flocks corraled at night were occasional. There is no reason why pumas would not attack vulnerable and available free-ranging flocks, considering that the only reason to occasional and not systematic predation to corraled stock is explained by risk aversion due to proximity to households (Mazzolli et al., 2002). Further evidence of puma population recovery was collected from 2003 to 2005, during which ranches that had never had livestocked attacked suffered losses to puma, demonstrating that pumas were reaching areas further into open grasslands than previously recorded. At least two ranchers were known to keep free-ranging sheep in the grasslands for over 20 years up to 2004, with not a single depredation incident. When pumas moved in, attacks became frequent and ranchers had to move the herds to enclosures during the night (Mazzolli, 2006).

Statistics of puma occurrence are difficult to obtain in Brazil. Livestock depredation and occurrence of puma are officially recorded by a specialized center of the federal environmental agency (Cenap) centralized in São Paulo. It was founded in 1994, much at the same time when pumas were already showing up (Mazzolli, 1992, 1993; Mazzolli et al., 1997), thus unable to report cases prior to that. Lack of reliable voluntary information from the public obtained while granting permits for predator removal (Mansfield, 1997), or during compensation schemes (Wagner et al., 1997), as obtained elsewhere, limits the available information at the broad geographical scale. Country legislation do not allow any type of hunting or harvesting of wildlife in Brazil, and compensation scheme inexist (Verdade and Campos, 2004). Hard proof of puma presence at the wide scale has to be often

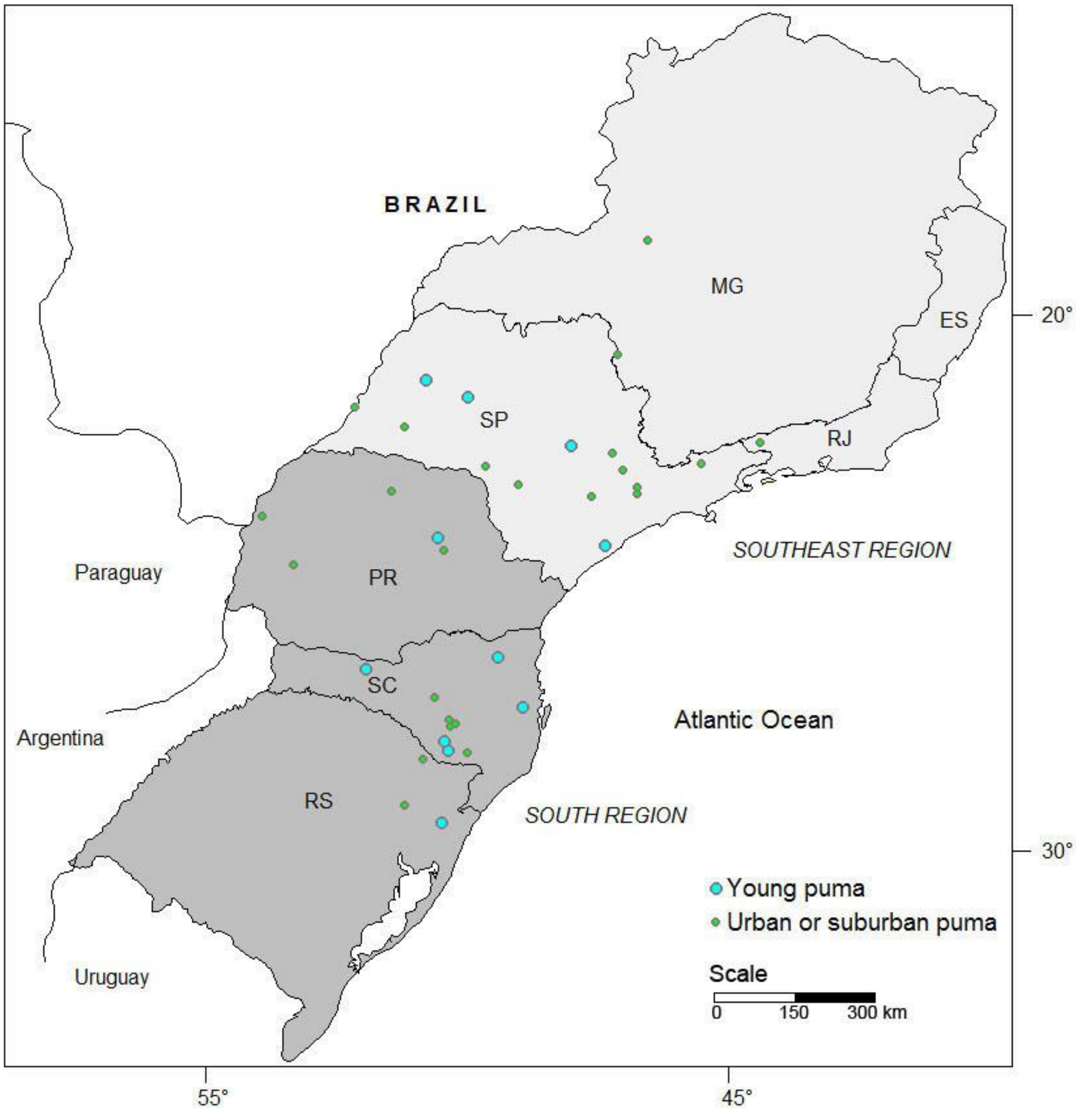

Figure 5. Location of puma occurrence sites in suburban and urban areas in south and southeast Brazil during the period 2004-2011, and records of young pumas from 1988-2011, demonstrating that pumas are reproductively active in the areas they have recolonized. Data from Tables 4 and 5 (appendix).

obtained from oportunistic information from the media or by (and this is hard to obtain) convincing ranchers to reveal their catch of poached pumas in their private properties, precluding any need for computer-intensive work to crunch large statistical databases on puma occurrence. In spite of that there is substantial evidence that recolonization expanded to urban and suburban areas following decline in deforestation, restraint of poaching, and sudden cases of puma depredation by the late 1980s and early 1990s. Pumas had not been recorded in urban areas prior to 2004, irrespectfully of the information source: news media, literature, or data collected directly by the author increasing in frequency since then (Figure 4). Records of pumas in urban and suburban areas were spatialized together with recent records of young wild pumas, to add to our understanding of distribution of cases and to compile evidence of breeding populations (Figure 5).

Prior to 2009, the Mata Ciliar Association, an NGO which maintains a Wildlife Rehabilitation Center since 1997, had never received claims of pumas in urban areas. From 2009 to 2010, the organization received eleven calls involving claims of pumas in the metropolitan area of Campinas alone (Crawshaw, 2011). The growing number of occurrence of pumas in urban areas are not conventionaly or consensually attributed to increase in numbers in the wild population, rather, it is often attributed by lay people as a result of urban expansion into the wilderness areas. However, large towns that may function as substantial barries to wildife dispersal represent only a fraction of the total landscape in the study area (IBGE, 2009), and except in high demographic concentrations of human population where pumas are known to be completely absent, such as most of the coastal plains of Santa Catarina and Rio Grande do Sul (Mazzolli, 1993), there is no reason to believe that pumas are in fact encrouched by urban expansion, not at least to a point of having to live in urban areas for lack of alternative habitat. Further, there is a well characterized human migration from rural to urban areas in S and SE regions (IBGE, 2010) that may be resulting in a decrease, even if momentaneous, of human interference in puma habitats.

Another usual but easely disregarded argument is that pumas would be seeking towns because of lack of prey in the wild. In fact, if prey is scarce in wild habitats, it would not be more readly available in towns. Furthermore, pumas are not known to feed on garbage like oppossums, foxes, and coyotes, in such amounts that would allow them to have a sustainable diet (although they could make a service by eliminating stray dogs and cats). Instead, pumas have a territorial social structure, in which youngsters of about 20 months disperse to find their own territories (Anderson, 1983; Seindensticker et al., 1973). That means that as the number of individuals increase, they have to find territories outside those that are alredy owned by older individuals, a process that eventually will expand the total land area occupied by a given puma population accordingly. Should the population of pumas increase to a point of saturation in wilderness areas, pumas will then start occupying suboptimal habitats such as urban and suburban areas. The extent into which they can adapt to live in these environments, even if having to use hunting grounds in more suitable landscape, are not know, as pumas are sistematically removed or translocated when found near humans, (as in those cases reported here). Due to a recent change in public opinion, pumas are being tolerated near human dwellings in some areas of North America, allowing scientists to investigate novel aspects of puma-human interactions under such conditions (e.g. McKinney and Poppenberger, 2008; Knopf et al., 2011).

CONCLUSION

Unregulated logging and associated occupation of primitive areas by settlers are a plausible explanation to the decline of puma populations during the 1960s and 1970s. The economic crises from decrease in timber harvesting following forest overexploitation produced a release into habitat pressures that may have created conditions for puma recovery, an effect that was magnified by a rural migration of people to urban areas. This situation was latter enhanced by laws that enforced protection of the habitats and fauna. Pumas were shown not to have gone extinct from the landscape during the most critical periods of habitat modification in S and SE Brazil, between 1960 and 1970, likely surviving in small numbers in discrete patches, much like a metapopulation (Hanski and Simberloff, 1997). Although there was no evidence of breeding populations during that period, it is highly unlikely that individuals consisted entirely of dispersing individuals given the extent of the land area covered by these records.

Evidence of recolonization by pumas came from field studies at the Tablelands of S Brazil, during the periods 1988-1995 (Mazzolli, 1992; 1993; Mazzolli et al., 1997) and from 2004-2005 (Mazzolli, 2006). During the first period, sheep flocks were still raised free-ranging, and at first ranchers were not aware of what was striking their flocks. During the second period, large sheep flocks were no longer raised free-ranging due to the intensity of predation by pumas, ranchers all knew about the puma, which was now also reaching small flocks raised in less vulnerable areas farther from forests, in grasslands areas. During the 2004-2005 period, pumas further expanded their range by reaching vacant range in the rural landscape in the tablelands, begining also to show as road kills or in urban areas, with numbers of occurrence growing steadly since.

Finally, it should be added that a recent study of Tableland pumas found that this population has gone through a bottleneck (Castilho et al., 2011), corroborating the evidence of range reduction and posterior expansion as discussed. The recolonization of the puma was partially a product of the conservation policy that provided full protection status to the Atlantic forest. Policies such as those in which conservation decisions are made prior to ecosystem collapse may save millions, or even billions of dollars, that would otherwise be needed to be invested to recover species at the brink of extinction (such as the Florida panther mentioned above). The recolonization of pumas, however, should not be taken for granted. As human population continue to encroach natural areas causing habitat reduction and fragmentation, monitoring of threatened wildlife should be a priority, large-scale and continuous process supportive to decision-making at different management levels.

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APPENDIX

Table 1. Extent of deforestation in the Atlantic Forest of Brazil by period.

Period	Extent (ha)
1985 - 1990	466.937
1990 - 1995	500.317
1995 - 2000	445.952
2000 - 2005	174.828
2005 - 2008	102.938
2008 - 2010	31.195

Table 2. Extent of deforestation in the Atlantic Forest of south and southeast regions of Brazil by period, excluding Restinga (beach forest) and Mangroves.

States	% Deforestation by period			
	1995 - 2000	2000 - 2005	2005 - 2008	2008 - 2010
South region				
Rio Grande do Sul	0.52	0.30	0.31	0.18
Santa Catarina	Not available	2.03	1.19	0.17
Paraná	4.34	1.44	0.51	0.17
Southest region				
São Paulo	1.65	0.18	0.11	0.02
Rio de Janeiro	0.48	0.07	0.13	0.03
Espírito Santo	1.19	0.16	0.12	0.05
Minas Gerais	2.80	1.46	1.23	0.45

Table 3. Historical records of puma occurrence in south and southeast regions of Brasil, obtained mostly by collecting specimens that had been poached or by inspecting specimens in museums (Mazzolli, 1992).

Locality	Town/State	Approximate coordinates	Type of record	Sex	Museum-number	Date
South region						
-	Urubici/ SC	28° 01'38"S 49°36'45"W	Mounted specimen	—	MHS-no #	1970
-	Urupema/ SC	27°57'59"S 49°51'42"W	Skull	Female	UFSC-0351	~1984
Estr. Dona Francisca	Joinville/ SC	26°16'34"S 49° 02'05"W	Skull	Female	UFSC-0381	~1976
Alto Palmeiras	Rio dos Cedros/ SC	26°33'02"S 49°22'56"W	Skull	Male	UFSC-0318	1982
-	Bom Jesus/ RS	28°47'36"S 50°14'34"W	Skull an pelt	Male	UFSC-0344	1987
-	Urubici/ SC	28° 08'23"S 49°28'32"W	Skull and pelt	Male	UFSC-0387	1989
-	Alfredo Wagner/ SC	27°48'45"S 49°20'20"W	Skull	Male	UFSC-0557	1990
-	Joinville/ SC	26°11'59"S 48°58'59"W	Skull	Male	UFSC-0559	1969
-	Lontras/ SC	27° 09'02"S 49°34'40"W	Skull	Male	UFSC-0386	1979
-	Siderópolis/SC	28°32'52"S 49°33'00"W	Skull	Male	UFSC-0319	~1973
-	Alfredo Wager/ SC	27°50'21"S 49°27'52"W	Skull	Male	Private	1990
Tainhas	Cambará do Sul/ RS	29° 00'43"S 50° 07'48"W	Skull	Female	UFSC-0605	1998
Alto Palmeiras	Rio dos Cedros/ SC	26°37'41"S 49°17'45"W	Skull	Female	UFSC-0320	Prior to 1988
Alto Palmeiras	Rio dos Cedros/ SC	26°39'29"S 49°26'37"W	Skull	Female	UFSC-0352	1988
-	Curitibanos/ SC	27°11'20"S 50°26'20"W	Skull and pelt	Female	Private	1991

Table 3. Continued.

-	São Joaquim/ SC	28°23'25"S 50° 00'39"W	Skull and pelt	Female	UFSC-0606	1991
-	Ponte Serrada/ SC	26°37'11"S 51°54'19"W	Skull and pelt	Female	UFSC-0333	1986
-	Jaquirana/ RS	28°54'36"S 50°18'59"W	Skull and pelt	Female	UFSC-0397	1989
-	Alfredo Wagner/ SC	27°52'04"S 49°19'25"W	Skull and pelt	Female	UFSC-0396	1985
-	Bom Jesus/ RS	28°44'55"S 50° 08'15"W	Skull and pelt	Female	UFSC-0373	1988
-	Curitiba/ PR	25°27'39"S 49° 4'55"W	Vidolin et al., 2004	—		1989
Southeast region						
-	Paraopeba/ MG	19°20'41"S 44°28'40"W	Skull	Male	MNRJ-0381	Prior to 1992
-	Anhembi/ SP	22°46'40"S 48°17'20"W	Skull and pelt	Male	MZUSP-10351	1964
-	Anhembi/ SP	22°53'29"S 48°14'41"W	Skull and pelt	Male	MZUSP-08878	1959
Subaúna	Mogi das Cruzes/ SP	23°21'26"S 46°10'27"W	Skull and pelt	Male	MZUSP-27764	1970
-	Boa Esperança do Sul/ SP	21°41'23"S 48°38'32"W	Skull and pelt	Female	MZUSP-10467	1964
-	Anhembi/ SP	22°50'31"S 48° 01'01"W	Skull and pelt	Male	MZUSP-09418	1961
-	Valparaíso/ SP	20°49'10"S 51°30'57"W	Skull	Male	MZUSP-03801	1932
-	Anhembi/ SP	22°41'08"S 47°58'19"W	Skull and pelt	Female	MZUSP-09010	1959
-	Anhembi/ SP	22°37'56"S 48°12'48"W	Skull and pelt	Female	MZUSP-09425	1961
-	Boa Esperança do Sul/ SP	22°13'26"S 48°23'57"W	Skull and pelt	Female	MZUSP-9811	1962

Table 3. Continued.

-	Anhembi/ SP	22°57'16"S 47°56'33"W	Skull and pelt	Female	MZUSP-10352	1964
-	Anhembi/ SP	22°38'52"S 48°26'11"W	Skull and pelt	Female	MZUSP-09637	1962
Serra da Cantareira	SP	23°22'41"S 46°40'33"W	Skull	Female	MZUSP-20935	1987
-	SP	—	Skull	Female	MZUSP-01637	1904

Table 4. Records of puma occurrence in urban, exurban and suburban sites in south and southeast regions of Brazil.

S/N	Locality/ category	Town/State	Approximate coordinates	Type of record	Source	Handled by the author
South region						
1	Bairro Gethal/ suburban	Lages/ Santa Catarina	27°47'42.45"S 50°18'1.66"W	Carcass	Gomes, 2008	No
2	Bairro Tributo/ exurban	Lages/ Santa Catarina	27°40'47.79"S 50°18'16.98" W	Livestock depredation	This research, 2011	Yes
3	Cadeado / exurban	Lages/ Santa Catarina	27°45'39.97"S 50°11'53.17" W	Road kill	Correio Lageano, 2008	Yes
4	Bairro Santa Isabel / suburban	São Joaquim/ Santa Catarina	28°16'44.62"S 49°57'36.01" W	Road kill	Correio Lageano, 2009	Yes
5	Bairro Bosque / suburban	Curitibanos/ Santa Catarina	27°17'12.33"S 50°35'26.31" W	Captured and translocated	Augusto, 2004	Yes
6	Bairro São Luiz / suburban	Canela/ Rio Grande do Sul	29°22'26.99"S 50°48'18.92" W	Carcass (shot)	Vieira, 2009	No
7	Bairro Sta Corona/ suburban	Caxias do Sul/ Rio Grande do Sul	29°12'27.04"S 51°10'33.97" W	Sighting and tracks	Victória, 2008	No
8	Rua Camélia/ urban	Corbélia/ Paraná	24°47'51"S 53°18'0"W	Captured and transferred to a zoo in Cascavel	Leitóles, 2011	No
9	Rua Frei Gaudêncio/ urban	Tibagi/ Paraná	24°30'57"S 50°24'34"W	Captured and translocated	Silva, 2011	No
10	Rua Alberto Jackson Biyngton Júnior/ urban	Altônia/ Paraná	23°52'1.81"S 53°53'32.29"W	Captured and translocated	Nunes, 2008	

Table 4. Continued.

11	Rua Iratauá/ Vila Araponguinha	Arapongas/ Paraná	23°23'36"S 51°25'18"W	Captured and translocated	Luporini, 2010	
Southeast region						
1	Av. Carlos Rios/ suburban	Santa Cruz do Rio Pardo/ São Paulo	22°53'47"S 49°36'52"W	Captured and translocated	Folha, 2011	No
2	Bairro Costa Azul/ urban	Avaré/ São Paulo	23°15'39"S 48°59'20.77"O	Captured and translocated	Tomazela, 2011	No
3	Rua Capitão Oliveira Carvalho, Jardim Rincão/ urban	São Paulo/ São Paulo	23°26'17.37"S 46°43'38.18"W	Captured and translocated	Valota, 2011	No
4	Cosmópolis/ exurban	Campinas/ São Paulo	22°39'45"S 47°11'43"W	Captured and translocated	AmbienteBrasil, 2010	No
5	Jardim Panorama/ urban or suburban	Vinhedo/ São Paulo	22°59'12"S 46°59'54"W	Captured and translocated	Globo, 2009	No
6	Residencial Lago Azul/ urban	Araçoiaba da Serra/ São Paulo	23°28'14.35"S 47°35'6.87"W	Captured and translocated	Tomazela, 2009	
7	Rua Antônio Marinho de Carvalho Filho/ urban	Presidente Epitácio/ São Paulo	21°46'37.67"S 52° 7'21.43"W	Captured and translocated	Bonato, 2011; O Globo, 2011	
8	Urban or suburban	Martinópolis/ São Paulo	22° 9'1"S 51°10'36"W	Captured and translocated	Globo, 2010a	
9	Av. Tonico Lenci/ bairro Lago Azul/ urban	Franco da Rocha/ São Paulo	23°18'8.74"S 46°43'0.74"W	Captured and translocated	Spigliatti, 2011	
10	Rua José de Santana/ urban	Patos de Minas/ Minas Gerais	18°35'26"S 46°30'54"W	Capture followed by death	Cury, 2011	
11	Urban	São Tomás de Aquino	20°46'50"S 47° 5'53"W	Captured and translocated	EPTV, 2010	
12	Distrito de Bulhões/ exurban	Resende/ Rio de Janeiro	22°28'S 44°22'W	Captured and translocated	Globo, 2010b	
13	Capivari	Campos do Jordão/ São Paulo	22°43'10"S 45°33'55"W	Video-capture	Globo, 2011	

Table 5. Evidence of breeding population. Wild young pumas recorded in South and Southeast regions of Brazil.

Locality	Town/State	Approximate coordinate	Type of record	Source	Handled by the author
South Region					
RPPN Caraguatá	Antônio Carlos	27°27' 13"S 48°57' 01"W	Camera-trap	Graipel, ME, 2010	no
Alto Palmeiras	Rio dos Cedros/ SC	26°33'2"S 49°22'56"W	Carcass	Mazzolli et al., 2002	yes
Fazenda Tozo (currently Araucarias National Park)	Ponte Serrada/ SC	26°45'48.00"S 51°54'13.00"W	Embryos	Mazzolli and Da-Ré, 1988	yes
Km 21	Lages/ SC	28° 1'28"S 50°28'45"W	Captured young, hand raised, died after 1 year	Mazzolli (pers. com.)	yes
Fazenda Três Capões	Lages/ SC	28°12'47"S 50°20'52"W	Photograh	Pozenatto (photograph), 2011	yes
Fazenda Monte Alegre	Telêmaco Borba/ PR	24°15'27.93"S 50°33'8.62"W	Captured female and yearling; young captured and hand raised	Mazzolli, 2000, 2010	yes
Flona São Francisco de Paula	São Francisco de Paula	29°25'45"S 50°23'41"W	Camera-trap	Marques and Ramos, 2003	no
Southeast region					
Estrada Córrego Borboleta (Guararapes)	Guararapes and Valparaíso/ SP	21°14'44"S 50°45'15"W	Capture	Gomes, 2006	no
Juréia-Itatins Ecological Station	Iguape/ SP	24°25'S 47°20'W	Sighting	Martins et al., 2008	no
Fazenda Samambaia	Promissão/ SP	21°35'8"S 49°58'35"W	Capture	Correio de Lins, 2006	no
Northeast São Paulo	Luis Antônio and Santa Rita do Passa Quatro/ SP	22°30’S 48°00’W	Feacal DNA	Miotti et al., 2011	no