Poaching in non–volant mammals in the Neotropical region: the importance of a metric to assess its impacts

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Abstract

Poaching in non–volant mammals in the Neotropical region: the importance of a metric to assess its impacts. Much of the information on the hunting of mammals in natural environments is not performed in a standard way and is usually dispersed by different areas or regions that have different environmental structures. This limitation prevents the detection of trends and patterns such as which biomes are under more pressure and what are the rates and level of impact. We aimed to review the scientific literature on poaching of non–volant mammals to evaluate the impact at different study sites in the Neotropical region. We found that in more than half of these studies (66/112, 59%), the main objectives were related to characterizing hunting activity while the potential impact of the hunting was not assessed. Evaluating the poaching through a metric assessment using qualitative and quantitative variables was the main objective in only 58 articles. We classified the hunting events as subsistence in most cases (46/58, 79%), as illegal in a few case (12/58, 21%) and as legal in one study only (1/58, 2%). Based on this extensive review of scientific literature, we propose a metric assessment that can be performed in natural reserves and can lead to extensive monitoring on mammal populations through training on how to gauge this geo–referenced data.

Key words: Conservation, Extinction, Hunting, Mammals, Standard monitoring

Resumen

La caza ilegal de mamíferos no voladores en la región neotropical: la importancia de evaluar sus repercusiones con un parámetro. Gran parte de la información sobre la caza de mamíferos en ambientes naturales no se recaba de forma estandarizada y generalmente se dispersa en zonas o regiones distintas que tienen estructuras ambientales diferentes. Esta limitación impide la detección de tendencias y pautas como las relacionadas con los biomas que padecen más presión o los índices y el grado de repercusiones. La finalidad de este trabajo es examinar las publicaciones científicas sobre la caza ilegal de mamíferos no voladores, con vistas a evaluar las repercusiones en diferentes sitios de estudio de la región neotropical. Encontramos que en más de la mitad de estos estudios (66/112; 59%), los objetivos principales estaban relacionados con la caracterización de la actividad cinegética, pero no se evaluaban las posibles repercusiones de la caza. Solo 58 artículos tenían el propósito de evaluar la caza ilegal mediante una evaluación paramétrica utilizando variables cualitativas y cuantitativas. En el presente estudio clasificamos los episodios de caza como de subsistencia (46/58; 79%), ilegales en unos pocos casos (12/58; 21%) y legales en un único estudio (1/58; 2%). Sobre la base de este amplio examen de las publicaciones científicas, proponemos una evaluación métrica que puede llevarse a cabo en reservas naturales y que permite hacer un seguimiento exhaustivo de las poblaciones de mamíferos gracias a la formación impartida sobre cómo analizar estos datos georreferenciados.

Palabras clave: Conservación, Extinción, Caza, Mamíferos, Seguimiento estandarizado

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Introduction

Human activity has deeply changed most ecosystems in many regions of the world (Steffen et al., 2015), causing widespread loss of biodiversity (Vellend et al., 2007; Arroyo–Rodriguez et al., 2013; Newbold et al., 2015), changes in community structure (Dornelas et al., 2014), and loss of ecosystem functions and services (Mitchell et al., 2015). Tropical forests are one of the biomes most threatened by human activities, and each year about 13 million hectares of these forests around in the world have been devastated (Myers et al., 2000). Exploitation of plant and animal resources in a non–sustainable approach in the natural landscape have led to biodiversity loss, pollution, invasion of exotic species, local extinction of native species (Cardinale et al., 2012), deforestation and habitat fragmentation (Laurance and Bierregaard Jr., 1997; Laurance, 1999). Tourism, hunting, agriculture and livestock practices also affect biodiversity and the survival of species (Cullen et al., 2000). Loss of habitats and hunting of species are considered the main threats to the maintenance of non–volant mammal populations (Redford, 1992; Peres, 2001; Milner–Gulland and Bennett, 2003).

Excessive removal of specimens from nature is a major threat to world fauna (Robinson and Redford, 1991; Bennett and Robinson, 2000a; Alves et al., 2012). Several studies show that hunting activities in the Neotropics are generally carried out in an uncontrolled manner, the impact of which makes populations unviable and natural resources unsustainable for ecosystem function (Hill and Padwe, 2000; Bodmer and Robinson, 2006; Fernandes–Ferreira et al., 2012). Much information on the hunting of mammals in natural environments is focuses on one or few species. In addition, this information is not standardized through a general protocol, and is dispersed from locations or regions with different environmental structures. This lack of standardization prevents the detection of trends and patterns concerning those biomes that are likely under highest pressure, and the quantification of the rate and level of the hunting impact.

We performed a review based on the information published in scientific journals on hunting in non–volant mammals in the Neotropical region. This review of the literature aimed to evaluate the use of metric assessment and the impact of hunting at several study sites in the Neotropical region. We sought to answer the following questions: i) for which biome have most studies been performed to evaluate the impact of hunting on mammals?; (ii) how many studies have evaluated the events and classified illegal or subsistence hunting?; iii) which metric assessment was used to evaluate the hunting impact in each study?; iv) has the metric assessment used to test the impact of hunting produced a statistically significant result?; and (v) can hunting records help to build a metric assessment to monitor impact of hunting?

Three electronic databases were used to search the scientific literature: ISI Web of Science, Google Scholar and Scielo. The search terms used were entered in the categories 'Title, abstract and keywords' and 'Topic' (TS). The search was based on seven sets of keywords, equally applied to the three databases. The main set referred to variations in hunting terms (impact studied) and included 'Hunt*' OR 'poach*' OR 'bushmeat'. The main set was crossed separately with five other sets referring to the object of the study (mammals) and locality (Neotropical Region) through the Boolean operator AND: ('mammal*') AND ('Neotropic*'). We restricted our search to articles published in three languages: English, Portuguese and Spanish. We considered only studies published from 1920 until 20 XII 2017, the date the search was conducted.

Humans and hunting: contextualizing this interaction

Wildlife has been a major resource for humans for the past six million years (Stanford and Bunn, 2001). Throughout our history, humans have interacted with wild mammal species of many different forms (Happold, 1995). Relationships thus vary according to different human cultures and are reflected in the negative or positive effects on the wild mammals involved (Leopold, 1959; Bodmer et al., 1997; Alves et al., 2009). Animals have been used over time for multiple purposes. They have not only provided food, but have also been used in the creation of artifacts, for transportation, as a source of beauty and inspiration, and as symbols of gods in religious rituals (Ripple and Perrine, 1999; Alves et al., 2012). Some species, such as felines, are hunted and killed because they represent risks to human life or domestic livestock, while others, such as rodents and some species of medium–sized mammals, pose a threat to crops (Treves et al., 2006; Mendonça et al., 2011; Macedo et al., 2015). This ambiguity in the interaction between human and animals is common in many cultures and depends on the species involved (Antonites and Odendaal, 2004; Alves et al., 2012; Alves and Souto, 2015). Indeed, in agricultural societies, hunting involves a dual relationship of familiarity and friendship with domestic animals, and hostility and aggression with the wild and mysterious world (Macedo et al., 2015). Hunting, especially in rural areas, tends to promote a rapprochement or rejection relationship with wild animals and tends to be transmitted over generations of human settlements in natural environments.

Hunting in the Neotropical region

The Neotropical region extends from Central America (including Tropical Mexico) to southern South America. This biogeographic region is characterized by significant biotic and climatic diversity (Morrone, 2014). It comprises 78 ecoregions formed predominantly by tropical and subtropical forests and open formations interrupted by rivers (Morrone, 2014).

Hunting of wild animals occurs throughout the Neotropical region, being carried out by indigenous, rural, and urban populations (Becker, 1981; Cullen et al., 2000; Fernandes–Ferreira et al., 2012). Hunting can be considered a cultural trait that is strongly

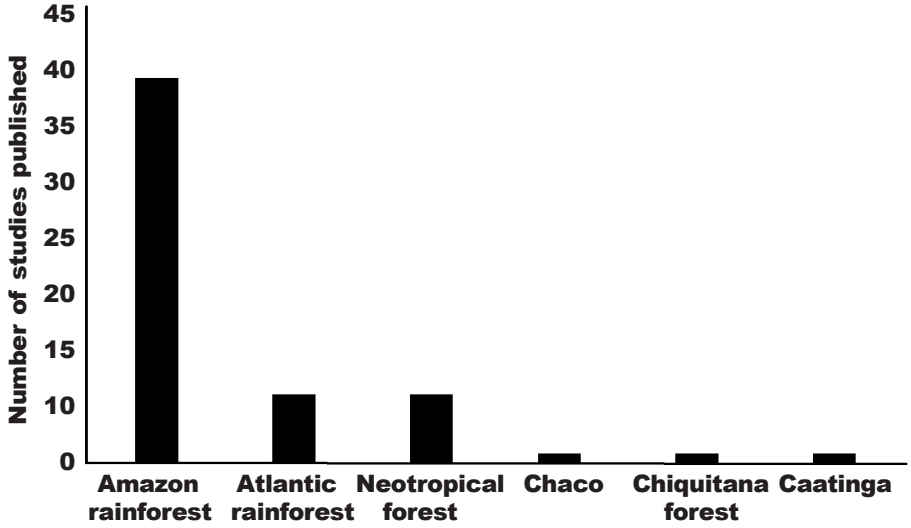

Fig. 1. Scientific publications that evaluated the impact of hunting on non–volant Neotropical mammals classified by types of environment. This figure was based on the 58 scientific publications evaluated.

Fig. 1. Publicaciones científicas que analizaron las repercusiones de la caza de mamíferos no voladores en la región neotropical, clasificadas por tipo de ambiente. Este gráfico se basa en las 58 publicaciones científicas estudiadas.

rooted in the Neotropics; it involves several aspects, depending on the human community in question and the region considered. The considerable progress in living conditions recorded in the second half of the twentieth century resulted in unprecedented urbanization, as well as an improvement and dynamization of the productive processes of animal protein (meat) and its derivatives. Together with the advancement in the perception of values concerning the importance of preserving natural resources, society has begun intensive discussion on hunting. Many groups have advocated an unrestricted ban on hunting, especially sport hunting (Leopold, 1959; Collazos et al., 1960; Pierret and Dourojeanni, 1966).

In the Neotropical region, hunting began to be studied at the beginning of the 20th century in order to characterize the activity with a cultural focus (Leopold 1959; Collazos et al., 1960; Pierret and Dourojeanni, 1966). However, it was not until the end of this century that studies began to focus on the hunting impact on wildlife (Bodmer et al., 1988; Paz y Miño, 1988; Peres, 1990). Of the 112 scientific articles reviewed, the main objective in more than half (66/112, 59 %) was to characterize the hunting activity only; the potential impact was not evaluated. Only 58 of the articles used a metric be it qualitative or quantitative –as the main objective to evaluate the hunting (table 1s in supplementary material). Of these, 38 studies published were carried out in the Amazon (about 70 %), followed by 10 studies in Neotropical Forest in general (17.3 %), eight studies in the Atlantic Forest (13.7 %), and only one study in the Bolivian Chaco and one in the Brazilian Semi–Arid region (1.7 %) (fig. 1).

The importance of hunting as a source of animal protein was evidenced in the first reports about the Amazon. In 1864, naturalist Henry Bates described hunts and the habit of local populations along the Amazon River to consume wild animals (Bates, 1864). Many studies on hunting among mestizo and indigenous populations have been carried out in the Amazon, especially since 1970. In that decade the availability of protein foods was already discussed as a limiting factor for human groups (Gross, 1975) as was the importance of hunting as a source of protein and fat for the Amazon populations (Ayres and Ayres, 1979). The hunting practiced by mestizo and indigenous populations of the Amazon was compared at the end of the 1980s, as biological factors such as density and abundance of species, and cultural factors, such as food and technical restrictions of hunting, were crucial to differentiate between these human groups (Redford and Robinson, 1987). In the 1990s, it was suggested that human population growth and settlement age (a supposed index of time to familiarize with the local environment and fauna) were associated with the negative effects of hunting on vertebrate fauna (Vickers, 1991; Redford, 1992). Since 2000, several aspects related to the sustainability of hunting in tropical forests have been studied (e.g. Bennett and Robinson, 2000a), although most of these studies have addressed subsistence hunting and few have addressed poaching (illegal hunting). Data from the available hunting studies classified the events as subsistence (46,78 %), while 12 (20 %) classified hunting as illegal and only one (2 %) as legal (supplementary material).

Currently, Amazonian rural communities continue to hunt, although the commercial exploitation of wildlife has become an illegal activity in Brazil since 1967 under the Wildlife Protection Act. (Law No. 5,197, of February 3, 1967). According to this law, hunting was prohibited even for human populations that depended on wildlife for food. Only in 1998, with the advent of the Environmental Crimes Law (Law No. 9,605, of February 12, 1998), was subsistence hunting recognized as a non–criminal activity provided that it was carried out 'in a state of need to quench hunger of the agent or his family'. However, this law does not correspond to the reality in the Amazon region, where the barter of hunting products for primary necessities is characterized as commercial hunting and is therefore considered illegal (Caughley and Gunn, 1996).

Mammals and hunting: impacts

Loss of habitat and overhunting of species are considered the main threats to the survival of many species of large forest vertebrates (Redford, 1992; Milner–Gulland and Bennett, 2003; Dirzo et al., 2014). Increased human density (Brook et al. 2006), the growth of access to new technologies (Vickers, 1991; Mena et al., 2000; Stearman, 2000), and the loss of traditional hunting practices (Leeuwenberg and Robinson, 2000; Mena et al., 2000; Stearman, 2000) have promoted the overhunting of populations of Neotropical mammals (Bennett and Robinson, 2000a, 2000b; Silvius et al., 2004). The overhunting of tropical forest vertebrates has led to the decline in population of many species (Bennett and Robinson, 2000b), causing extinctions of local and global species (Peres, 1990; Ulloa et al., 2004).

Hunting can affect mammalian populations (Chiarello, 2000; Peres, 2000b; Crawshaw et al., 2004) and change communities (Peres, 1990, 2001; Naughton–Treves et al., 2003), but it tends to be underestimated (Redford, 1992) due to lack of standardization and difficulties in detection (Peres et al., 2006). This occurs both in areas where there is anthropogenic habitat disturbance (Daily et al., 2003; Naughton–Treves et al., 2003) and in areas with little or no forest change (Redford, 1992; Peres, 1996; Peres and Lake, 2003), including within protected areas (Chiarello, 2000; Altrichter and Almeida, 2002; Olmos et al., 2004). Most hunted species are frugivorous and/or herbivorous (Peres, 2000a, 2000b; Townsend, 2000), and they play an ecological role in the dynamics of natural environments (Dirzo and Miranda, 1991; Wright et al., 2000; Stoner et al., 2007). The overhunting of large forest vertebrates can compromise important ecological processes for the maintenance of forest structure and species composition (Dirzo and Miranda, 1991; Wright et al., 2000; Dirzo et al., 2014), reducing long–term biodiversity (Terborgh, 1992, 2000).

Extirpation of species tends to compromise the ecosystem functionally and may result in the depletion of forest environments (Harrison, 2011). Population reduction of top–predators (e.g. *Panthera onca* and *Puma concolor*) due to systematic killing by hunting (Crawshaw et al., 2004) may result in increased prey species density, promoting alteration of community structure and overexploitation of resources by herbivores that previously had their populations controlled by these predators (Terborgh et al., 2001). In addition, human hunters often tend to hunt those species that top predators select as prey, such as ungulates and rodent species (Leite and Galvão, 2002), and this may reduce the capacity of a habitat to sustain populations of large carnivores. In the Neotropical region, primates, tapirs and carnivores are particularly vulnerable to overhunting due to their low intrinsic rates of natural growth, high longevity, long generation time, and low population densities (Bodmer et al., 1997; Cardillo et al., 2004). Populations of ungulates and large primates decline as soon as hunting becomes a chronic process (Peres, 2000b).

How has the hunting impact been assessed in the Neotropical region?

One of the most cited hypotheses in the field of Conservation Biology is undoubtedly Kent Redford's 'Empty Forest' (Redford, 1992). It has been proposed that we are moving towards a situation where extensive, seemingly intact forest areas present a series of ecological extinctions as a result of hunting and a supposed defaunation. Large species, especially mammals, could have such small populations that vital functions for the maintenance of ecosystems would be highly affected. In the long–term, therefore, the preservation of tropical forest vegetation would not be possible if the fauna were not also preserved (Redford, 1992). The question of 'empty forest' has also been evaluated considering the effects of hunting, showing the potential association between hunting and negative effects on the vegeation (Harrison, 2011). The species most appreciated by subsistence hunters are generally responsible for ecological interactions that directly influence plant regeneration (Dirzo, 2001; Wright et al., 2007; Terborgh et al., 2008). These interactions include predation of seeds before and after dispersion, primary and secondary seed dispersal, and leaf and grass herbivory (Wright et al., 2007). The consequences of deforestation from fauna hunting in forest dynamics include reductions in predation and dispersal of seeds, which may lead to changes in total recruitment of seedlings, composition, decreases in diversity of flora (Dirzo and Miranda, 1991; Terborgh et al., 2008; Dirzo et al., 2014), and even alterations of carbon stocks in tropical forests (Bello et al., 2015; Kurten et al., 2015).

Many studies based on the ‘empty forest’ hypothesis qualitatively compared the impact of hunting on wildlife in areas without hunting or hunting classified at different intensities. Of these 58 studies evaluated, 39 used a qualitative approach to characterize hunting and assess the impact on mammals (fig. 2A). The methods used to characterize the impact of hunting used in 95 % of the studies were: 20 studies used hunting intensity classes (low, medium and high) by locality and 18 relied on presence/absence data (i.e. with and without hunting) (fig. 2A). However,

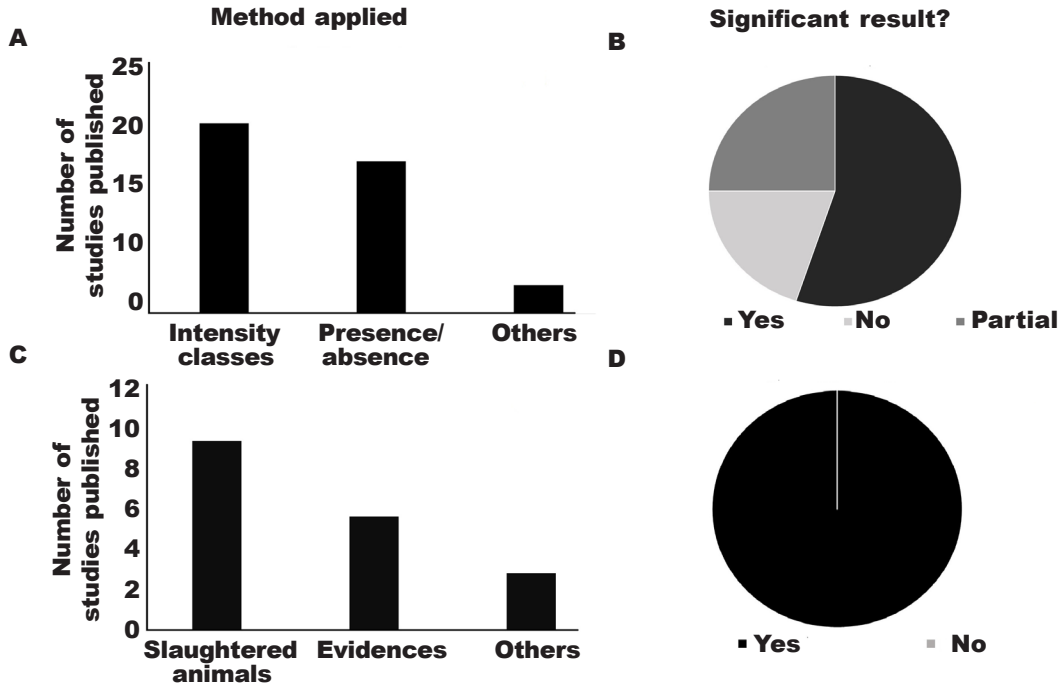

Fig. 2. Classification of scientific publications evaluating the impact of hunting on non–volant Neotropical mammals: A, metric estimated by the qualitative method; B, significance of the result found in each study that used the qualitative method; C, metric estimated by the quantitative method; and D, significance of the result found in each study that used the quantitative method.

Fig. 2. Clasificación de las publicaciones científicas que analizan las repercusiones de la caza de mamíferos no voladores en la región neotropical: A, parámetro estimado por el método cualitativo; B, significación del resultado obtenido en cada estudio que utilizó el método cualitativo; C, parámetro estimado por el método cuantitativo; y D, significación del resultado obtenido en cada estudio que utilizó el método cuantitativo.

using a qualitative approach to evaluate the impact of hunting, almost half of the studies did not find statistically significant results (fig. 2B).

Concomitantly, models were developed to quantitatively measure the sustainability of hunting in tropical areas, representing about 33 % (19/58) of the studies as shown in figure 2C (Robinson and Redford, 1991; Robinson and Bennett, 1999; Bodmer and Robinson, 2004). Of the 19 studies that assessed the impact of hunting quantitatively, 11 were for subsistence hunting in the Amazon Forest using the number of slaughtered animals as metric. This assessment is possible for subsistence hunting because the communities that practice hunting report the number of individuals that are extracted from nature. This metric cannot be applied to measure illegal hunting, however. Therefore, the eight studies that evaluated poaching used evidence of hunting as an indicator, but continued ranking the intensity of hunting. Some studies assume that the density of huntable species in non–hunting areas represents a precise estimate of the support capacity in a region, thus concluding the number of individuals an area could harbor (Caughley, 1977; Caughley and Sinclair, 1994). All 19 studies using a quantitative metric found a statistically significant result on the impact of hunting on mammals (fig. 2D).

The importance of a quantitative metric method to detect the poaching impact and long–term standardized monitoring

As previously reported, most studies that evaluated the impact of hunting considered subsistence hunting. To quantify the impact of hunting, the number of animals slaughtered (fig. 2C) was used as a metric assessment in most studies. For subsistence hunting, this metric may indicate an estimate of how species are being affected (Aquino and Calle, 2003; Peres and Nascimento, 2006; Parry et al., 2009), but for poaching it would not be possible to quantify, since there is no access to the actual number of animals killed. Quantifying the impact of illegal hunting is therefore challenging. A few studies have used hunting evidence as a metric to quantify impact (Chiarello, 2000; Wright et al., 2000), but they have used this

evidence as a general value, not considering that such evidence was not spatially distributed uniformly. Neither was the temporal distribution of this evidence considered. Although a quantitative metric was used, the studies were not performed in a standardized way that allowed comparison between different Neotropical regions. This emphasizes that in addition to a quantitative metric, it is necessary to have a minimum of possible standardization that provides a bigger picture of the impact on the mammals.

In this context, a quantitative metric assessment has been proposed. This approach considers the spatial distribution of hunting evidence per km^2 and allows the trends of this impact to be monitored over time (Ferreguetti et al., 2015, 2016, 2017). This metric will collect the evidence of illegal hunting in a standardized way over time. The metric can be generated by considering each poaching event separately (date, reserve where the event was recorded, location/region of the event, geographic coordinates and type of evidence collected). Any evidence of hunting can be georeferenced over time. Examples that can be considered as evidence of hunting to georeferenced: (1) hunting elements found such as traps or baited sites: leg–hold traps, snare traps, crushing or weight traps, fall–and–apprising traps ('arapucas'), cage traps, cartridges and archery traps, corral, pitfall, among others kind of traps; (2) direct evidence of the presence of hunters, such as encounters, slaughtered animals, and camps. Together with this georeferenced database, it is recommended to use the poacher's records by using camera traps to calculate the metric.

Based on the construction of this database of georeferenced hunting events it is possible to calculate a quantitative metric that consists of dividing the study area into 1–km^2 grids by positioning on a digital map of the target Reserve and identifying sample sites by each area size. For example, a Reserve of 100 km^2 will result in 100 grids with an intensity of hunting events per km^2.

Moreover, it is important to avoid counting the same record twice by removing the evidence found. Monitoring should be done on a regular basis, not exceeding a period of three months without monitoring. The metric proposed can be carried out in protected areas and can still rely on the population for a monitoring performance through training on how to gauge this georeferenced data and how to pursue conservation actions to mitigate the impact of hunting on mammalian species.

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