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Vulnerability of mammals to land-use changes in Colombia's post-conflict era

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Abstract

Colombia, one of the most biodiverse countries in the world, is entering a peaceful period after more than fifty years of armed conflict. Due to land use changes resulting from this new situation, negative effects on biodiversity, including mammals are expected. We think that mammal populations will be more sensitive in municipalities where activities related to post-conflict will be carried out. In that order, we aim to: 1) identify which mammal species would be more sensitive and 2) identify the critical regions where there is higher richness of sensitive mammals. We used the distributions of 95 mammal taxa and calculated a sensitivity index by combining four factors: 1) the proportion of each species distribution within protected areas in relation to their proposed extinction thresholds, 2) the proportion within post-conflict municipalities, 3) the proportion of five types of potential land use in post-conflict municipalities and 4) the threat status of each species. Using this index, we drew a map of species richness for mammals classified at high-risk and very high-risk categories. Primates were the most sensitive group to post-conflict changes. Urabá and the region near to the Serranía de San Lucas were the areas with the highest richness of sensitive species. We suggest using primates as flagship species to carry out conservation schemes in the post-conflict era in programmes led by local farmers and former fighters who have been reintegrated into civilian life.

Keywords

Armed conflict, biodiversity loss, flagship species, primates, protected areas

Introduction

After more than 50 years of armed conflict in Colombia, the Government and FARC (Revolutionary Armed Forces of Colombia), the oldest guerrilla army from Latin America, signed a peace agreement in 2016. One of the central points in such agreement is rural reform (Gobierno Nacional and FARC-EP 2016). As a consequence, it is expected that many people who suffered forced displacement will return to rural areas. This immigration process could represent a risk for biodiversity due to expansion of the agricultural frontier in formerly abandoned lands (Negret et al. 2017).

Colombia is a megadiverse country (Andrade 2011) that encompasses two biodiversity hotspots (Myers et al. 2000) and holds 518 mammal species (Ramírez-Chaves et al. 2016). Mammals are important due to their economic importance and ecological value (Ceballos and Brown 1994), but their populations around the world are threatened by several anthropogenic factors, including those related to armed conflicts (Ceballos and Ehrlich 2002, Dudley et al. 2002, Daskin and Pringle 2018). Notwithstanding, there are no specific studies analysing the relationship between warfare and mammals population in Colombia.

War in Colombia has had both negative and positive effects on biodiversity. Forests from many areas were cleared for illicit crop plantations, mining and land grabbing for cattle ranching. In addition, terrorist attacks spilled oil causing pollution over vast areas (Dávalos et al. 2011, Sánchez-Cuervo and Mitchell 2013, Asociación Colombiana del Petróleo 2014). On the other hand, due to the violence, vegetation regrowth and absence of human disturbance in many abandoned areas may have preserved biodiversity (Sánchez-Cuervo and Mitchell 2013).

In the current post-conflict era, many social and environmental changes are expected in Colombia (Baptiste et al. 2017, Negret et al. 2017). Experiences from other countries have shown that some activities related to post-conflict, such as resettlement and rural reforms, can have negative effects on biodiversity (Suarez et al. 2018). These effects may be exacerbated in Colombia by the low representation of threatened areas and endemic species within protected areas (Forero-Medina and Joppa 2010). In the Colombian case, we expect biodiversity –and specifically mammal species– will be affected mainly in those areas where post-conflict activities will be carried out. As many mammal species are sensitive to human activities, it is important to identify which areas and species would need more attention in that new scenario. With the premise that environmental changes will follow in municipalities where peace agreements are to be implemented, we aim to: 1) identify which mammal species are most sensitive and, 2) identify critical regions where negative effects on mammals are most likely.

Methods

Study Polygons selection

We selected mammals from six orders (Artiodactyla, Carnivora, Cingulata, Perissodactyla, Pilosa and Primates) with known distributions in Colombia. Species distributions

were downloaded from the IUCN Red List of Threatened Species (IUCN 2017) and the digital tool BioModelos (Instituto Humboldt 2017).

We considered as post-conflict areas, the polygons retrieved from the Departamento Administrativo Nacional de Estadístca (DANE 2017) of the 170 municipalities, where activities related to rural reform will be carried out to develop the rural economy, according to Decree 893 of 2017 (Ministerio de Agricultura y Desarrollo Rural 2017). Additionally, we used polygons of national protected areas retrieved from the Colombian National Parks (Parques Nacionales Naturales de Colombia 2017) and polygons of the types of potential land use retrieved from the Instituto Geográfico Agustín Codazi (IGAC 2018).

Risk evaluation

To identify the sensitivity of mammal species to post-conflict land use change, we calculated the proportion of its distribution that overlaps with post-conflict areas and protected areas. Additionally, we calculated the proportion of species distribution that overlaps with five main types of potential land use for Colombia, only within municipalities of post-conflict in QGIS software (2.14.8-Essen). Then, we developed a sensitivity index (*S*) for each species considering four factors:

$$S = TS + PAET + Post + PLU$$

where *TS* is the threat status according to the classification of the IUCN Red List of Threatened Species (IUCN 2017). *PAET* is an index that relates the proportion of the distribution of each species within national protected areas and its proposed extinction threshold. *Post* is the proportion of the distribution of each species within post-conflict areas and *PLU* is the proportion of the distribution of each species within a type of potential land use in post-conflict municipalities. *TS*, *PAET*, *Post* and *PLU* ranged between 0 and 5 each. Thus *S* varied from 0 to 20 and was classified into five categories: non-risk ($S = 0$), low-risk ($0 < S < 5$), middle-risk ($5 \leq S < 10$), high-risk ($10 \leq S < 15$) and very high-risk ($S \geq 15$).

As detailed information about population structure of each species across all the country is unknown, we therefore used the threat status (*TS*) of the species as a proxy of extinction proneness since it is related to a quantitative measure of reduction in population size in a temporal scale and geographic range (IUCN 2012). We assigned *TS* values for each species according to the following: Least Concern (LC) = 0; Data Deficient (DD) or Not Evaluated (NE) = 1; Near Threatened (NT) = 2; Vulnerable (VU) = 3; Endangered (EN) = 4; Critically Endangered (CR) = 5.

Considering that any place outside protected areas will be more vulnerable to changes in land use in the post-conflict era, it is expected that species with a higher proportion of their distribution within protected areas will be less vulnerable. Then, we considered each protected area as a 'patch of habitat' and that each species would need an amount of habitat (i.e. proportion of its distribution overlapped with protected areas) equivalent to its extinction threshold to maintain a population in

equilibrium (Fahrig 2001). Previous simulations highlight that the four main factors determining extinction threshold are (from least to most important): habitat pattern, matrix quality, dispersal rate and reproductive rate (Fahrig 2001). As body weight of mammals is negatively related to reproductive rate (Western 1979), we expect that the greater the body size, the higher the extinction threshold. Thus, we used body mass of each species (or the average mass of the genus) (Jones et al. 2009) to classify them into four categories: small (< 1 kg), medium (1–5 kg), large (5–15 kg) and very large (> 15 kg). We defined the extinction threshold for each species knowing *a priori* that a species like *Panthera onca* (a very large species) need at least 50% of its distribution within protected areas to maintain its subpopulations in lower risk (de la Torre et al. 2018). Then, we used species body weight to classify the extinction threshold for our species as 50% of remaining habitat for very-large, 40% for large, 30% for medium and 20% for small species. We used each threshold as the amount of habitat needed within protected areas to guarantee adequate protection for each species, and calculated the relationship between the proportion of the distribution of each species within national protected areas and its proposed extinction threshold (*PAET*) as:

$$PAET = \frac{5}{\left(\frac{pa * 4}{et}\right) + 1}$$

where *pa* is the proportion of the distribution of each species within national protected areas and *et* is the extinction threshold applied for the species considering its body weight.

We assumed that the greater the post-conflict area overlapped with species distribution, the greater the negative effect on the species. However, the effects will be more negative in municipalities where more people will return in the post-conflict era since this immigration process is a driver of environmental impacts in the post-conflict era (Suarez et al. 2018). Consequently, we used the number of displaced people in each municipality between 1993 and 2013 (Consejería Presidencial para los Derechos Humanos 2015, Unidad para las Víctimas 2018) as the surrogate number of people that might return to each municipality. Then we calculated the proportion of the distribution of each species within post-conflict areas (*Post*) as:

$$Post = 5 * \left(\sum_{i=1}^{n} A_i * disp\right)$$

where A_j is the proportion of a species distribution within the municipality *i* and *disp* is a factor associated with each municipality according to the number of displaced people (dp): *disp* = 0.7 (dp < 10,000), *disp* = 0.8 (10,000 ≤ dp < 25,000), *disd* = 0.9 (25,000 ≤ dp < 50,000) and *disp* = 1 (dp ≥ 50,000).

Peace agreements between the Colombian Government and FARC have a special focus on rural reform to carry out agricultural activities according to the potential land

use (Gobierno Nacional FARC-EP 2016). Negative effects on biodiversity depend of the land use, being most negative on croplands and least negative on uses that maintain natural vegetation to some extent (i.e. extractivism) (see Newbold et al. 2015). We selected five main types of potential land use proposed for Colombia: conservation, forestry, agroforestry, cattle ranch and agriculture. These potential uses are based on the natural capacity of the land to support a given activity under sustainable conditions (IGAC 2012). We calculated the proportion of the distribution of each species within a type of potential land use in post-conflict municipalities (PLU) as:

$$PLU = 5 * \left(\sum_{j=1}^{n} A_j * lu \right)$$

where A_j is the proportion of a species within a type of potential land use j and lu is a factor associated with each land use according to the intensity of use: lu = 0.2 (conservation), lu = 0.4 (forestry), lu = 0.6 (agroforestry), lu = 0.8 (cattle ranch) and lu = 1 (agriculture).

Finally, we created a grid on a map of Colombia using squared cells of 0.1° (approximately 10.6 km). Then the species richness was calculated in each cell by overlapping all species distributions and considering that a given species was present if the cell occupancy was greater than 50%. We created two maps: one considering all present species and another considering only species classified at high-risk and very high-risk according to our sensitivity index to identify critical regions where negative effects on mammals are most likely. Both maps were designed using the SAM Software Version 4.0 (Rangel et al. 2010).

Results

We obtained spatial distributions of 95 taxa: 44 primates, 26 Carnivora, nine Artiodactyla, seven Pilosa, six Cingulata, and three Perissodactyla (see Suppl. material 1: Table S1: mammal species used in the analysis). A total of 36.84% of all species were classified as low-risk, 48.42% as middle-risk, 13.68% as high-risk and 1.05% as very high-risk (represented only by the primate species *Plecturocebus caquetensis*). No species was classified as non-risk (Figure 1). With 12 out of 44 species classified as high-risk and very high-risk, primates are the mammal group that is most sensitive to post-conflict changes in Colombia. *Tapirus bairdii* (Perissodactyla) and *Mazama temama* (Artiodactyla) were also classified as high-risk (Figure 2).

Amazon and some points from the Orinoco region (including the eastern side of the Cordillera Oriental) were the areas with greatest overall species richness, followed by the Serranía de San Lucas and the transition zone between the Caribbean and the Pacific region near to the Urabá Gulf (Figure 3a). The areas with highest richness of sensitive species were those near to Urabá Gulf (municipalities of Turbo, Chigorodó

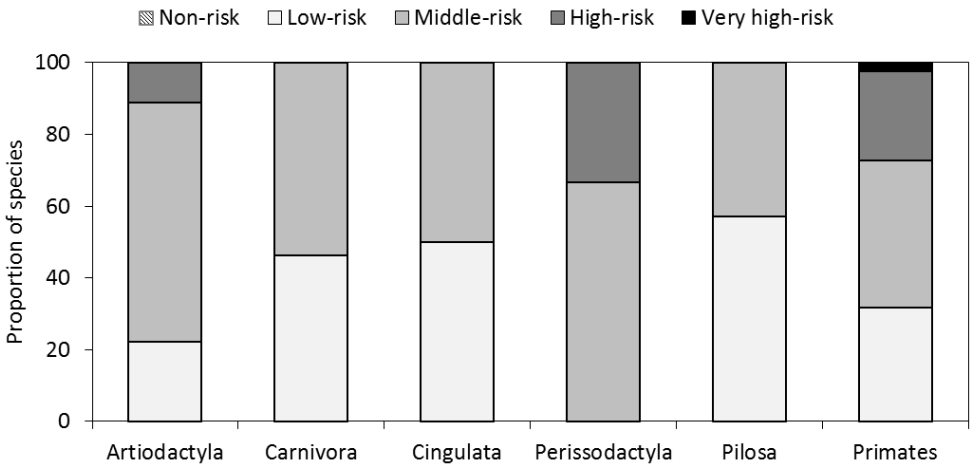

Figure 1. Proportion of mammal species amongst six orders within each category of sensitivity in the Colombian post-conflict era. Non-risk (S = 0), low-risk (0 < S < 5), middle-risk (5 ≤ S < 10), high-risk (10 ≤ S < 15) and very high-risk (S ≥ 15).

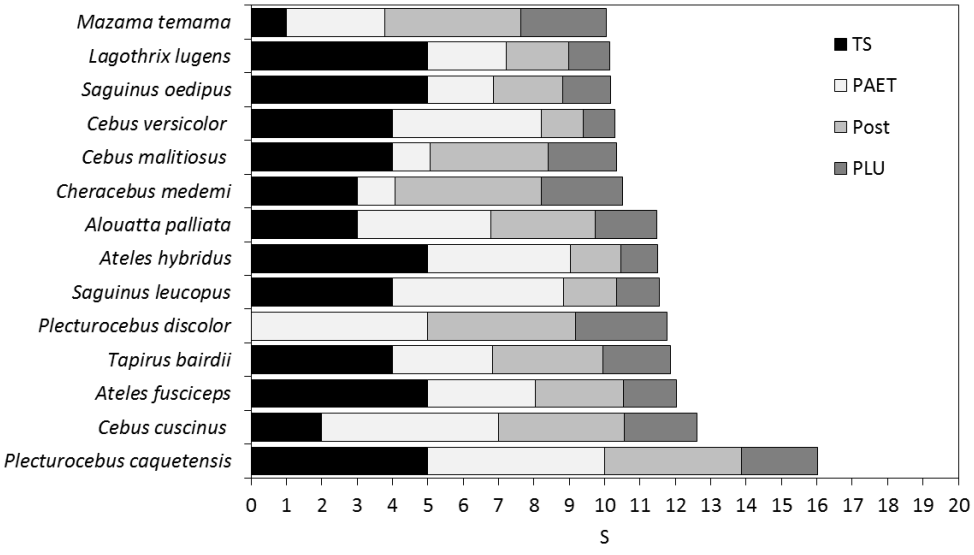

Figure 2. Most sensitive (***S*** ≥ 10) mammal species in Colombian postconflict areas and the contribution of each of the four factors to the sensitivity index (S). ***TS***: threat status; ***PAET***: relationship between the proportion of the distribution of each species within national protected areas and its proposed extinction threshold; ***Post***: proportion of the distribution of each species within post-conflict areas; ***PLU***: proportion of the distribution of each species within a type of potential land use in post-conflict municipalities.

and Mutatá in Antioquia, Tierralta in Cordoba and Riosucio in Chocó) and the region near to the Serranía de San Lucas (municipalities of Yondó, Segovia, El Bagre and Remedios in Antioquia and Arenal, Cantagallo, Morales, San Pablo, Santa Rosa del Sur and Simití in Bolivar) (Figure 3b).

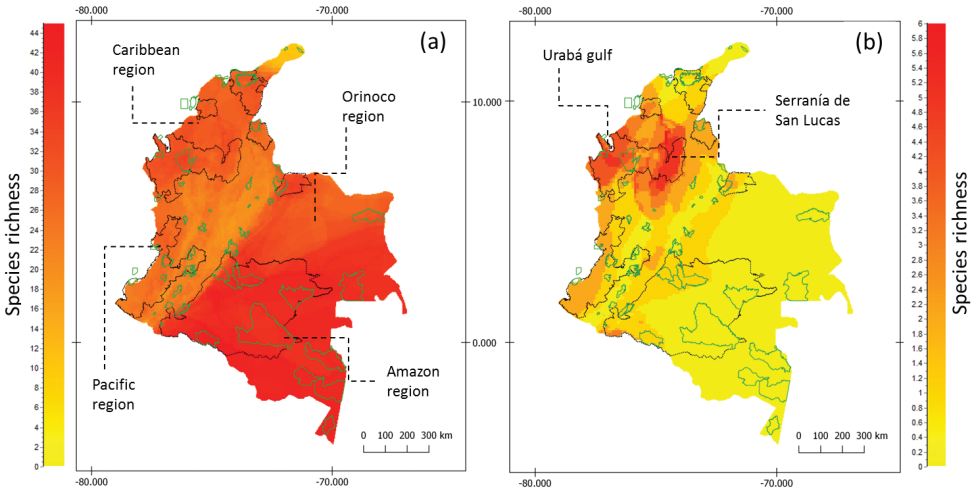

Figure 3. a Mammal species richness in Colombia considering the distribution of 95 taxa of six orders. **b** Critical regions (Urabá and Serranía de San Lucas) where negative effects on mammals are most likely considering only those species classified as high-risk and very high-risk in post-conflict era ($S \geq 10$). Black polygons correspond to the 170 municipalities used as post-conflict areas and green polygons to protected areas.

Discussion

Increased attention has been given to the effects of warfare on biodiversity in the last two decades and Colombia is one of the areas of special attention (Dudley et al. 2002, Hanson et al. 2009, Lawrence et al. 2015, Daskin and Pringle 2018, Hanson 2018, Suarez et al. 2018). Colombia not only holds the Tropical Andes and the Tumbes-Chocó-Magdalena as biodiversity hotspots, but is also part of the Amazon region, the greatest extension of tropical forest on the earth (Myers et al. 2000, FAO ITTO 2011). Preserving these areas is not only of national concern, but also of global interest due to their contribution of these regions to global biodiversity, high endemism of plants and fauna and regulation of global climate (Myers et al. 2000, Werth and Avissar 2002, Malhi et al. 2008).

We found that post-conflict alterations in Colombia represent a threat to many mammal species and that primates are the most vulnerable group to such alterations. As forest dwelling animals, primates are highly sensitive to deforestation, as well as other animals such as the Baird's Tapir, that also depends on closed canopy forests (Matola et al. 1997). Other international examples support the fact that many species might be highly impacted by forest loss during the post-conflict era in Colombia. When civil war ended in Nicaragua, deforestation increased because many people returned to rural areas (Stevens et al. 2011). In addition, rapid forest loss was also documented in post-conflict periods in Bosnia, Liberia, Rwanda and Sierra Leone (Suarez et al. 2018).

Other human activities, such as hunting, may increase the threats to some primate species. For example, four Atelids and the Central American Red Brocket, which are classified as high-risk species in our study, face known hunting pressure (Weber and Gonzalez 2003, de Thoisy et al. 2005, Aquino et al. 2009) concomitant with post-

conflict land-use change. Previous studies demonstrated that in the Rwanda Republic and the Democratic Republic of Congo for example, bushmeat hunting increased after peace negotiation, affecting ungulates and the emblematic flagship species *Gorilla* spp. (Plumptre et al. 1997, Glew and Hudson 2007). Increased hunting also caused wildlife decline in Cambodia during its post-conflict era (Loucks et al. 2009).

We found that areas near to the Serranía de San Lucas and Urabá gulf are the most critical regions since they host the largest numbers of mammals considered at risk according to our sensitivity index. Historically, some guerrillas in San Lucas imposed environmental restrictions for locals to preserve the area, such as prohibition of hunting and logging and they planted landmines to avoid mining and logging by foreign people (Dávalos 2001). Nevertheless, after the peace agreement, FARC abandoned this area, ending this protective measure. The National Liberation Army (ELN) is another armed group that still occupies some areas in Colombia and has similar environmental policies (Dávalos 2001). However, ELN and the Colombian Government have been under negotiations since 2017 and a similar effect on biodiversity could arise should such negotiations succeed, not only due to the absence of environmental control imposed by guerrillas, but also due to the changes related to land use inherent in the new peace agreement. On the other hand, armed conflict displaced more than 10,000 people in some municipalities from Urabá (see database in Consejería Presidencial para los Derechos Humanos 2015 and Unidad para las Víctimas 2018). As a consequence, we expect the return of a large number of people to this region, leading to deforestation, increased hunting and raising the risk of local extinctions.

The relationship between biodiversity and warfare can be separated in three stages: 1) preparations, 2) war and, 3) post-war activities (Machlis and Hanson 2008). As the Colombian conflict is old (more than 50 years), it is difficult to gather information related to biodiversity in the former stage (i.e. pre-war). However, current geopolitical and social scenarios provide an opportunity to guide the Colombian government in thinking about the last two stages. Concerning the second stage, there are other armed groups in Colombia disputing territories in a few regions of the country and they have dominion or take advantage of the gap left by the former armed groups. In this case, the government can carry out actions to reduce the negative effects of this regionalised war on biodiversity and environment. Such actions may include (1) increasing research, (2) applying the resolutions of the United Nations against pollution in war time and the environmental protection in conflicts areas and (3) taking into account the "International Day for Preventing the Exploitation of the Environment in War and Armed Conflict" (Hanson 2018). Concerning the third stage, primates, similar to birds (Ocampo-Peñuela and Scott 2017), could be targeted by touristic activities in the post-conflict era or became flagship species in a "green economy based on low-emissions land/resource use systems" (Baptiste et al. 2017).

Increasing the protected areas should be a government strategy associated with the rural reform to prevent biodiversity losses during the post-conflict period. The critical regions for the implementation of such protected areas would be areas near to Urabá Gulf and Serranía de San Lucas, since they harbour most of the high-risk species from

this study. Most of the species classified as high-risk or very high-risk in our analysis have less than 10% of their distribution under legal protection. The most critical case was *Plecturocebus caquetensis*, the single very high-risk species in our analysis that occurs outside of the most critical areas in post-conflict: its distribution does not overlap any protected area, its entire distribution is within post-conflict area and it was recently classified amongst the world's 25 most endangered primates (Defler et al. 2017). This species, similar to others, demands urgent conservation schemes, such as economic incentives for the establishment of private protected areas and agro-silvoforestry plots (Baptiste et al. 2017) in programmes led by local farmers and former fighters who have been reintegrated into civilian life. This option is highly feasible taking into account the forestry vocation of Colombia (IGAC 2012). For this reason, the government needs to consider the current types of potential land use of Colombia in the post-conflict era to avoid biodiversity loss, as evidence around the world has shown that some environmental drivers of change in post-conflict countries are "ineffective land use planning" and "unsustainable agricultural practices" (Suarez et al. 2018).

Conclusions

Around the world, in the last half of the past century, more than 80% of armed conflicts took place within biodiversity hotspots (Hanson et al. 2009). Therefore, mitigating warfare impacts is imperative for biodiversity conservation, as many conflicts of state-based violence and non-state violence have been increasing in the last century throughout the globe, including countries such as Mexico, Somalia, Syria and Myanmar (UCDP 2018), which host biodiversity hotspots (Myers et al. 2000, Mittermeier et al. 2004). As other conflicts are certain to occur in the future, approaches such as ours may aid other conflict areas to promote biodiversity conservation when these conflicts are over.

When the environmental context is not cohesive with peace agreements, several drivers of environmental change can emerge (Suarez et al. 2018). In that order, conservation planning is vital for peace building in regions of high biodiversity (Lujala and Rustad 2012). Some countries reached a peace agreements in the last 30 years, for example: El Salvador (1992), Rwanda (1993), Bosnia and Herzegovina (1995), Sierra Leone (2000), Liberia (2003) and Burundi (2008) (Suarez et al. 2018). These six countries and Colombia have a common denominator and can prospectively induce positive changes within their territories if peace is ongoing, because high biodiversity make people more resilient when war has devastated their society (Hanson 2018). Since biodiversity can be seen as an opportunity for peace building, it is important to work together with locals, researchers and former fighters with financial support to bring welfare to the people without threatening the biodiversity (Hanson 2018).

This first evaluation of the possible consequences of the peace agreement between Colombian government and FARC on mammals can help to improve the current scenario of peace in Colombia. Fourteen species classified at high-risk or very high-risk cat-

egories need to be included in schemes for conservation based in local initiatives led by former fighters and victims of armed conflict. Experiences from Asia, Africa and Central America have shown how the lack of planning can have negative effects on biodiversity, since impacts on the environment increase after cessation of conflict or peace treaties (Loucks et al. 2005, Glew and Hudson 2007, Suarez et al. 2018). In the current scenario of political division in Colombia after the negative result of a plebiscite for peace in October 2016, there is a challenge for the new government that started on August 2018, independent of its political ideology, to include in its environmental strategies the creation of protected areas in the biodiversity hotspot Tumbes-Chocó-Magdalena, specifically in Urabá and Serranía de San Lucas regions. As well as the sustainable use of the biodiversity (e.g. ecotourism approaches with locals and former fighters), using mammals as flagships species, especially primates, to prevent the biodiversity loss and its consequences. Additionally, we think the same analysis with other biological groups would be extremely useful for the design of conservation schemes, land use policies and rural reform programmes in order to prevent extinctions and to decrease threats to the species in Colombia, one of the most biodiverse countries in the world.

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Supplementary material 1

Table S1

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Data type: species data

Explanation note: Mammal species used in the analysis and value of each factor to calculate the sensitivity index of each species (*S*) is available for this article online.

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