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Text T1. Country-specific threats for jaguars in NW South America

North-western Venezuela

Recently, the main causes of jaguar population decline in NW Venezuela have been deforestation and conflicts with cattle production, while in the past, intensive hunting stimulated by the pelt trade was an important factor (Hoogesteijn & Mondolfi 1990a,b, Payan & Trujillo 2006, Jędrzejewski et al. 2011, 2015, 2017a, 2017c). Deforestation to increase cattle pasture and agricultural areas continues. Such deforestation usually leads to increased conflicts between jaguars and cattle ranchers and retaliatory killing of jaguars. Killing jaguars in cattle ranching areas, especially in the Llanos and Zulia state, is very common and widespread. Ranchers use specialised, highly effective methods to kill jaguars, including dogs, cage traps, poison, baiting, or waiting at the predation site. These two mutually related processes (deforestation and retaliatory killing of jaguars) are the main drivers of jaguar local extirpations and the decrease of jaguar range in Venezuela (Hoogesteijn et al. 1993, 2002, Jędrzejewski et al 2017a, 2017c).

Killing jaguars by regular (subsistence) hunters is also common in Venezuela, and at the national scale it is the reason for the highest annual mortality of jaguars (Jędrzejewski et al. 2017c). However, such hunting usually has a less destructive impact on jaguar populations than retaliatory killing, because it is spread over very large, sparsely populated, forested areas and its intensity per unit area is much lower than retaliatory killing. Jaguars are hunted by regular hunters at chance meetings during hunts for other species. After killing a jaguar, both ranchers and hunters collect and often try to sell jaguar skins, fangs or skulls or use them to decorate their houses. Hunters in Venezuela often consume or sell jaguar meat and collect jaguar fat for traditional medicines (Jędrzejewski et al 2017c). Trading jaguar products in Venezuela is very common, but it has rather a local character. However, recently the sacrifice of live felids including jaguars and trade of their body parts for “santería” religious rites, has been reported in Venezuela (Mendez 2021)

Colombia

The current (2020) jaguar range in Colombia is 28% (~250,000 km^2) smaller than the one estimated by the IUCN in 2000 (Jędrzejewski et al. 2023a) indicating a very fast decline of jaguar populations. The main threats are the intensive economic development of many areas and the transformation of forests and other natural lands to agriculture and cattle pastures (Payán et al. 2013a. 2016). Large areas of the Llanos have been converted to pastures and industrial monocultures (e.g., rice, oil palm), for example in Vichada, where jaguars are strongly persecuted because of attacks on cattle (Payán et al. 2013b). Recently, rapid deforestation and development of agriculture areas, especially plantations of rice, corn, soybeans and oil palm, have become widespread, causing fast reduction of jaguar habitat in several parts of Colombia (Payán and Boron 2019). For example, in 2019, inside three national parks (Tinigua NP, Macarena NP, and Chiribiquete NP) 95 km^2 were deforested; high deforestation rate was also recorded in the Llanos

in Arauca and Casanare (Paz Cardona 2021a, IDEAM 2019). In general, increasing deforestation rates emerged since the Peace Agreement in 2016 (Álvarez 2001, 2003, Davalos 2001, Villamil 2020), reaching 2,200 km^2 in 2017 and still growing (IDEAM 2019, FCDS 2020). The Amazon and Andes experienced the highest deforestation rates but with considerable impact also in Chocó, Orinoco, and Caribbean regions. Additionally, the development of transportation infrastructure, especially road networks, is causing habitat fragmentation and isolation, as well as increasing accessibility to natural areas. Some new highways are an important barrier for the dispersion of jaguars and other animals, like the highway Marginal de la Selva that interrupted the continuity between La Macarena and Chiribiquete national parks at the Andean foothills in the Colombian Amazon or the Ruta del Sol in the middle Magdalena River valley (Payán et al. 2013c). Mining, in the Cauca River, San Lucas mountains, and in the Colombian Amazon, is causing habitat deterioration and water pollution, as well as higher rates of illegal jaguar hunting (Davalos, 2001, Payán et al. 2016). Conflict with cattle, and the consequent retaliatory killing of jaguars, is still among the most important threats for the species in Colombia, with frequent events and records of killing across most regions of the country (Aconcha-Abril et al. 2016).

Ecuador

The main threat and cause of jaguar population decline in Ecuador has been habitat loss. For example, by 1988 in western Ecuador only 8% (5,800 km^2) of native forests below 900 m of altitude remained pristine (Dodson & Gentry 1991). Another important threat is prey depletion; in eastern Ecuador, where large tracts of habitat remain, jaguar densities were positively associated with prey density, which was lower at areas with higher accessibility to indigenous hunters that extract bushmeat for consumption and trading purposes (Espinosa et al. 2014, 2018). Finally, jaguar killing due to conflict with cattle ranchers is another important threat for the conservation of the species (MAE & WCS 2014), and jaguars are often killed in rural areas and even within protected areas (Torres-Jiménez 2014). Also, recent research suggests the traffic of jaguar parts for the Chinese market is an important threat in South America (Morcatty et al. 2020, Polisar et al. 2022).

Peru

Deforestation is the leading threat facing jaguar conservation in Peru, not only because this activity directly reduces or eliminates jaguar habitat, but also because it is followed by an increased access to the forest, increased hunting pressure, infrastructure development, agriculture, cattle ranching, and conflicts with jaguars. Peru lost more than 28,800 km^2 of forest between 2001 and 2018, which constitutes a loss of 3.7% of the forested area making it the seventh highest deforestation rate in the world, with Brazil at the top of the list (Finer & Mamani 2018b, GFW 2019). Major drivers of deforestation in Peru are agricultural expansion (cattle ranching, palm oil, coffee, and cacao plantations) and “migratory” agriculture (people changing their crop areas due to soil impoverishment), followed by illegal crops (mainly coca). Road construction is also a major threat, and a gateway for deforestation and hunting (GGGI 2015, Espinosa et al. 2018), for example the Interoceanic Highway crossing the southern departments of Cusco and Madre de Dios.

Over the last decade, mining, especially for gold, has caused deterioration of jaguar habitat over extensive areas in Madre de Dios. Mining converts forests and soil into unrecoverable, polluted swamps and causes mercury poisoning of waters, which can have a direct effect on jaguar survival (Finer & Mamani 2018a, May Junior 2018). Logging is another widespread problem in the Peruvian Amazon, which in the long-term may cause habitat deterioration. The common delays in the titling of indigenous territories and the lack of the State actions when the titled communities denounce illegal invasions from third parties such as loggers or miners is an important threat to jaguars.

Targeted hunting, associated with the illegal wildlife trade is an increasing threat. There are several reports of jaguar parts, especially fangs, found in markets in Iquitos, Pucallpa and even Lima (Berton 2018, Braczkowski et al. 2019). A team of Mongabay (Berton 2018) journalists reported that in Iquitos, Loreto; in a single week they found 44 fangs, four skulls, five skins and 70 jaguar claws. Peru is a signatory member of CITES which prohibits any trade in jaguars or jaguar parts, but these laws need a stronger enforcement.

Little data exists on the extent of human-jaguar conflicts and retaliatory killings in Peru. However, given the relatively small extent of cattle ranching in the Peruvian Amazon we expect this to be less of a threat than in other South American countries such as Brazil, Venezuela or Bolivia. Interview data from the Brazil nut concession region of Madre de Dios show that fear is as much a driver for jaguar killing as retaliation for livestock loss (M. Tobler unpublished data), something that has also been shown in neighbouring Bolivia (Knox et al. 2019).

Amazonian Bolivia

Between the 1930's and the 1970's thousands of jaguars were hunted across their range in response to the demand generated by the international skin trade, causing declines or extirpations of many jaguar populations. In 1975 CITES legislation criminalised the trade, and by the 1980's this legislation had significantly reduced jaguar killing in Latin America (Hoogesteijn & Mondolfi 1990b, Payan & Trujillo 2006). More recently, deforestation and extensive expansion of agricultural areas, mainly soya plantations are the main threats, for example, around the city of Santa Cruz de la Sierra, and in the unique wetlands of Llanos de Moxos in the Beni Department (www.globalforestwatch.org). The Amazonian fires of 2019 and 2020 were also widespread in Bolivia causing significant habitat loss and impacting wildlife populations (Damasio 2019).

Another long-term problem in jaguar conservation are conflicts with ranchers and communities, caused by jaguar predation on livestock and the killing jaguars in retaliation (Villalva & Palomero 2019). For example, in 30 ranches in Beni department 93 jaguars were killed in 2010 (Inchauste Ibáñez 2015). The fear of jaguars can be an additional motivation to kill them in several areas (Knox et al. 2019). However, in several parts of Bolivia, jaguars are culturally worshiped by indigenous people and are rarely killed (Salinas 2010).

Since 2014, a major new threat has emerged in Bolivia from the illegal trade of jaguar products, especially fangs, destined for Asia (Nuñez & Aliaga-Rossel 2017, Verheij 2019, Mongabay Latam 2021, Polisar et al. 2022). Whilst most detected cases to date have direct links to China, the actual

hunting of jaguars (minimum of 200 jaguar deaths to date) is carried-out by Bolivians, and much of it is probably linked to the human-jaguar conflict (Arias et al. 2021). In a questionnaire survey, almost one third of rural respondents owned jaguar body parts, most commonly skins, fat and teeth for decorative, medicinal, and cultural purposes. Skins and other body parts of the jaguar (and other protected species) are openly traded and sold in provincial Bolivian cities and towns. Conservation interventions must address foreign and domestic trade chains (Arias et al. 2021).

Commercial markets for wildlife meat are mainly restricted to the rural areas in Bolivia. Therefore, depletion of the prey base is probably not a very significant threat for jaguars except in habitats near major cities and towns. Distance to roads is known to affect wildlife and the jaguar prey base in the Bolivian Amazon (Wallace et al. 2020).

Brazilian Amazon

The jaguar's distribution has decreased by 11% compared to its original area. Deforestation has been the main cause of this decline, causing extirpation of the species in several localities and deterioration of jaguar habitats in Rondonia, Pará, Maranhão, Mato Grosso, and Amazonas states (Fig. 2). A recent study shows that only from 2015 to 2019 nearly 1.8% of the jaguar population was displaced in the Brazilian Amazon (Menezes et al. 2021). Removal rate was estimated to be 0.56 jaguars/100 km^2/year in the arch of deforestation in Pará (Michalski et al. 2006). Considering that cattle ranching and soybean cultivation are the main drivers of deforestation in the Brazilian Amazon, the growing global demand for meat, dairy, and soybean products may result in further destruction of core jaguar habitat (Romero-Muñoz et al. 2020). This expansion, accompanied by the development of road systems, is opening access to formerly inaccessible areas and boosting illegal logging, mining, and hunting.

Jaguars are commonly poached in the Brazilian Amazon, even inside protected areas (Ramalho 2012, Carvalho & Morato 2013, Carvalho 2019). In Mamirauá (11,240 km^2) and Amanã (23,500 km^2) sustainable development reserves aproximatelly 110 jaguars were killed by hunters during 18 months of 2009–2010 (Ramalho 2012). Most hunts were opportunistic (55%) and occurred in the high-water season in the flooded 'varzea' where shooting jaguars resting on the trees above water is easy. Parts of dead animals (e.g. skins, skulls, teeth, claws, meat, and fat) were often collected and in about 60% of cases they were sold. Meat was consumed in 43% of cases. The main declared motivations to hunt jaguars were retaliation for livestock depredation and fear (Ramalho 2012). Jaguar poaching for illegal trade of jaguar body parts has increased recently (Morcatty et al. 2020, Romero-Muñoz et al. 2020; Menezes et al. 2021, Polisar et al 2022) and may be an important issue for conservation of the jaguar in the Brazilian Amazon in the future.

SOM Table T1. Importance of different threat categories for the decline of jaguar populations in each country, based on questionnaires filled by co-authors of this article. 1 – very important, 2 – important, 3 – little important.

Country	NW Venezuela	Colombia	Ecuador	Peru	Amazonian Bolivia	Amazonian Brazil
Habitat loss - deforestation (conversion of forest for pasture and agricultures)	1	1	1	1	1	1
Conflicts with cattle ranchers/ Retaliatory killing	1	1	3	2	2	1
Jaguar hunting and trade of jaguar parts	1	2	2	1	2	1
Infrastructure development and habitat fragmentation	2	1	1	2	3	2
Increase in human population densities	2	1	1	1	2	2
Mining of minerals /petrol and gas extraction	2	1	2	1	1	2
Prey depletion (due to overhunting)	2	3	1	3	3	3
Forestry/Logging	2	2	2	2	3	3
Poor law enforcement	1	2	2	1	2	1
Low ecological education level//low acceptance of jaguars	2	2	2	2	2	2

Conservation of the jaguar in NW South America – country-specific problems and goals

North-western Venezuela

In Venezuela, the jaguar is officially protected in the area north of the Orinoco river, however due to additional regulations, hunting for jaguars is illegal over the whole country (Venezuela 1996a, 1996b, Payan et al. 2023). Its current status in the national Red Book is Vulnerable A2cd (Jędrzejewski et al. 2015). Important problems are low levels of law enforcement and no national strategy or program for jaguar protection. In practice, only national parks and some other protected areas ensure a better protection of the species and its habitats, although national parks are also in severe difficulties because of the political and economic crisis of recent years (low salaries, lack of equipment), invasions, and illegal mining in some parks (Mongabay Latam EN 2018, Castillo 2020, De Sousa Infante 2020, RAISG 2020). Jaguar populations inside protected areas have higher chances of persistence (Jędrzejewski et al. 2017a, 2017c), because deforestations and cattle ranching are more limited, and possibly hunting is also less intense inside protected areas. However, there are very few protected areas in NW Venezuela and inside the jaguar range they cover only 26,500 km^2 (15% of jaguar range, Fig. 3, Table 1). Additionally,

invasions by local people followed by deforestation and cattle ranching are now a major problem in some national parks (e.g. Ciénagas del Catatumbo National Park in Zulia state, Puerto 2012).

To stop further degradation of jaguar habitats and jaguar population decline, the most urgent is to create new national parks, for example in the western Llanos in Hato Piñero and its surroundings (Cojedes state), in the confluence of Rio Apure - Rio Portuguesa and in the region of Caparo Forest (Barinas state), and also in Apure, Falcon, and Zulia states. It is equally important to strengthen the national park services and strengthen the role of national parks as environmental education centres.

Pro-environmental activity is not easy in Venezuela, nowadays. The political-economic crisis, recently deepened by international sanctions, cut off funding possibilities for field activities of any organizations, including governmental scientific agencies and the environmental ministry. The situation is still more complicated by a general decline of security, the largely uncontrolled power of the army, and by increasing threats from various criminal groups, including Colombian ones (descended from FARC, ELN, and other armed groups), that operate in vast areas of Venezuela (Mongabay Latam EN, 2018). In this situation, environmental law enforcement is very limited and, moreover, even monitoring of the current environmental problems is extremely challenging.

Colombia

The jaguar is a fully protected species in Colombia, with a different status for its two subpopulations. The population inhabiting the most western part of Colombia (Chocó region), is listed as Vulnerable in the Red Book of Colombian mammals (Rodríguez-Mahecha et al. 2006) and recently officially classified as Vulnerable by the Ministry of Environment and Sustainable Development (Resolution #1972, from 2017). The rest of the Colombian jaguar population is listed as Near Threatened (NT). The jaguar is also included in the appendix I of CITES approved by the Colombian government by the Law 17 of 1981. Jaguar conservation is receiving increasing attention at national, regional, and local levels and the main achievement is the growing public awareness regarding the need for jaguar conservation. That results in several national and regional conservation plans and assessments as well as including jaguar priority areas into territorial planning (Zárrate-Charry et al. 2018, Koprowski et al. 2019, Paz Cardona 2021b), and a considerable number of local and community-based conservation activities. For these reasons, jaguar hunting in various parts of Colombia appears to be less intense than in other countries, although there is very little field data to support this assessment. Workers of the national protected areas reported only 18 killed jaguars in the last 10 years. The rate of creation of new protected areas and recognition of indigenous territories has recently increased. However, some parts of the jaguar range in Colombia still remain without any protected categories (Fig. 3) and one of the most important conservation goals for Colombia is the creation of new national parks that constitute also very important jaguar-corridors, as in Serranía de San Lucas, Serranía de Perijá, in Middle Magdalena, in the Llanos, and in Chocó (Payán et al. 2016).

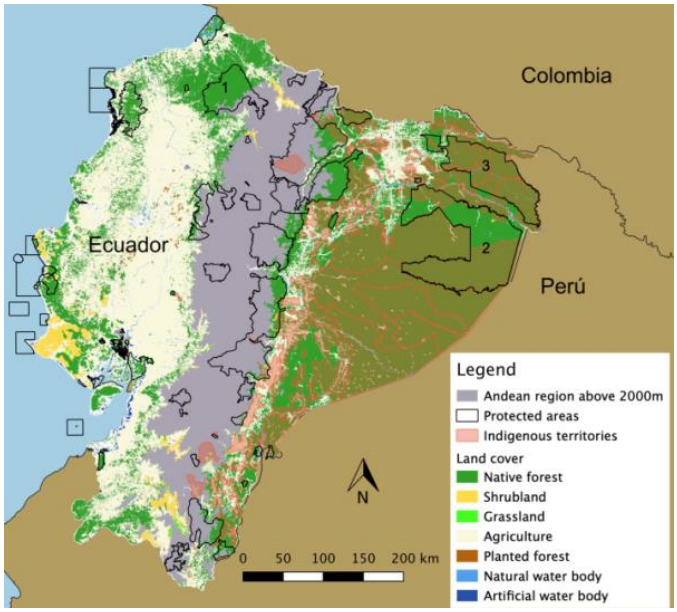
The political situation in Colombia is complicated and still far from true stabilization. The armed groups (FARC, ELN) and numerous new criminal groups formed out of the former paramilitary

organizations control large territories, especially in remote areas of Colombia, conducting illegal extraction of gold and other minerals, timber exploitation, and cultivation of drugs (Alvarez 2001, 2003, Rodríguez Mega 2017). For these reasons, many pro-environmental actions have been halted, for example the creation of a new protected area in Serranía de San Lucas. Publicising environmental problems or other pro-environmental activities in the regions of illegal exploitation of timber, gold, or other resources is highly dangerous. The numbers of environmentalists killed for defending nature are growing every year. In 2016, 37 people were killed, while in 2019 there were 64 murders, making Colombia the most dangerous place in the world for activists who seek to help protect land and other natural resources (Global Witness 2017, 2020, Tomassoni 2020).

Ecuador

In the last decade, interest in conserving the jaguar has increased significantly in Ecuador. In 2010, practically no local program existed to protect this species and by 2014, a Jaguar Conservation Action Plan was developed (MAE & WCS 2014). Currently the jaguar is one of the target species for conservation efforts led by governmental institutions (Ministry of Environment and Water and National Institute of Biodiversity-INABIO), and international conservation organizations (WCS and WWF); local NGOs are also becoming involved in actions to conserve this species. The jaguar is listed as Critically Endangered and Endangered in the west and east of the country, respectively (Espinosa et al. 2011a, 2011b), which means it is officially protected by Ecuadorian law (Libro IV, Art. 61, Texto Unificado de Legislación Secundaria de Medio Ambiente). Therefore, the capture, killing, exchange, commercialization or trade of live jaguars or their parts are subject to 1–3 years of imprisonment (Article 247, Código Orgánico Integral Penal of Ecuador).

Currently, about 80% of jaguar range in Ecuador is within protected areas or indigenous territories (Figs. 3 and SOM Fig. 1, Table 1). Future conservation goals include strengthening the management of protected areas and indigenous territories to promote the conservation of the species and addressing specific conservation needs such as: (1) reducing retaliatory killing related to conflicts with people, (2) reinforcing mechanisms to control illegal hunting, trafficking and trading of wild animals and their parts, (3) increasing connectivity between jaguar subpopulations and conservation areas, and (4) intensifying education and increasing ecological awareness of the society.



SOM Figure F1. Remaining jaguar habitat in Ecuador (native forest and shrubland under 2,000 m a.s.l.). Three largest protected areas for jaguar conservation: (1) Cotacachi-Cayapas Ecological Reserve, (2) Yasuní National Park, and (3) Cuyabeno Wildlife Reserve). Sources: Interactive map of protected areas and remnant vegetation, Ministry of Environment and Water (MAAE 2018, http://ide.ambiente.gob.ec/mapainteractivo/); Map of Indigenous territories, Amazon Geo-Referenced Socio-Environmental Information Network (www.amazoniasocioambiental.org).

Peru

Peru is a signatory party of CITES which regulates international trade of jaguar parts or live animals. Killing of jaguars, like all other wild animals, is prohibited, except for indigenous communities who may hunt animals for subsistence (Wildlife Law 29763/2015). Another exception is when a jaguar is a threat to human life, then it is allowed to use a weapon for self-defence (Article 308.C of the Peruvian Penal Code). It is categorised as Near Threatened (SERFOR 2018). Peru is among the countries with a fairly high proportion of the jaguar population living in protected areas or indigenous territories (Fig. 3, Tables 1 and 3).

There are 25 National Protected Areas within the jaguar distribution range in Peru with different levels of protection, from areas with strict protection like National Parks to areas that allow natural resource use such as Protected Forests or Communal Reserves (SERNANP 2020). The total area of protected areas is 171,400 km^2, constituting 28% of the jaguar range in Peru. Indigenous territories, which are also important for jaguar conservation, cover 190,700 km^2 (31% of jaguar range, Fig. 3 and Table 1). Furthermore, studies have shown that jaguars are still common outside of protected areas, with important populations occurring in logging concessions (Tobler et al. 2013, 2018) and Brazil nut concessions (M. Tobler unpublished data). Apart from some mid-elevation areas along the central Andes that have been highly deforested, and possibly areas along the main highways in Ucayali and Madre de Dios, there is little habitat fragmentation and connectivity is largely maintained (Fig. 2A).

Amazonian Bolivia

The jaguar is considered Vulnerable in Bolivia according to the National Red List (Ministerio de Medio Ambiente y Agua 2009) and a national action plan for the jaguar was recently published by the Bolivian Government (Ministerio de Medio Ambiente y Agua 2020) prioritising actions to combat the emerging illegal trade in jaguar parts, mitigate jaguar conflicts with cattle ranchers, and address a depleting jaguar prey base. In the last three decades, several conservation initiatives, involving various NGO's, are underway across the country, for example, in the Chiquitano Forest and the Greater Madidi-Tambopata Landscape (Painter et al. 2006).

During the 1990´s until 2004, the Bolivian government created a number of national protected areas which today, together with the regional protected areas, cover 39% (164,100 km^2) of the current jaguar range inside Amazonian Bolivia (Fig. 3, Table 1). The National Protected Area System (SNAP) includes relatively few national protected areas, but many of the national parks are relatively large which is important for jaguar conservation. Jaguars occur in most of the national protected areas (Noss et al. 2010) of which the following are particularly important, given their size: Madidi, Noel Kempff Mercado, Manuripi, San Matias, Pilon Lajas, Amboro, Carrasco, and Isoboro Sécure. Parallel to that, the Bolivian government formally recognised and titled a number of indigenous territories across the country. To date, titled indigenous territories cover 17% (72,800 km^2) of the jaguar range (Fig. 3, Table 1), with several others still waiting to be recognised and titled. Many of the indigenous territories are large, and their accompanying Life Plans (management plans including zoning) are compatible with jaguar conservation, since their development visions retain original vegetation cover in the vast majority of the land, and commit to sustainable use of natural resources.

Brazilian Amazon

The jaguar is listed as Vulnerable in the Brazilian Red List (MMA, 2014) and is recognised as a Brazilian biodiversity conservation symbol (MMA, 2018a). In 2009, Brazilian government adopted the National Action Plan as a tool for jaguar conservation (de Paula et al., 2013), which established priority actions to reverse the population decline trend. This plan has been recently updated (MMA, 2018b). Considering the large extent of the species occurrence in Brazil, the National Action Plan lists some specific actions for each biome. For the Brazilian Amazon, reducing habitat loss and hunting are crucial for the species long-term survival. The rapid habitat conversion in the last five years (~2.0%), mainly in the arch of deforestation, is of concern (Menezes et al. 2021) and improving law enforcement and education would play a critical role in reducing such trend. Despite the importance of the Amazon for the conservation of the jaguar there are only few long-term studies and conservation projects in the region. The Jaguar Conservation Program of Mamirauá Sustainable Development Institute is the longest such project in the region and has been running since 2004. Recently, the ICMBio's MONITORA Program has contributed to evaluate the species trend in several protected areas in the Brazilian Amazon showing the importance of the network of protected areas for the jaguar conservation.

SOM Table T2. Main conservation needs and conservation goals to stop jaguar decline in each country, based on questionnaires filled by co-authors of this article (only the most important are shown here)

NW Venezuela	Colombia	Ecuador	Peru	Amazonian Bolivia	Amazonian Brazil
Stopping deforestation	Stopping deforestation	Stopping deforestation	Stopping deforestation	Stopping deforestation	Stopping deforestation
Creating new/ strengthening existing protected areas	Creating new/ strengthening existing protected areas	Strengthening protected areas	Strengthening protected areas	Strengthening protected areas	Strengthening protected areas
Improving law enforcement/ reducing illegal kiling and trade	Improving law enforcement/ reducing illegal kiling and trade	Improving law enforcement/ reducing illegal kiling and trade	Improving law enforcement/ reducing illegal kiling and trade	Improving law enforcement/ reducing illegal kiling and trade	Improving law enforcement/ reducing illegal kiling and trade
Improving environmental education/ assisting ranchers to mitigate conflicts	Improving environmental education/ assisting ranchers to mitigate conflicts	Improving environmental education	Improving environmental education	Improving environmental education/ assisting ranchers to mitigate conflicts	Improving environmental education/ assisting ranchers to mitigate conflicts
Improving connectivity/ protecting ecological corridors	Improving connectivity/ protecting ecological corridors	Improving connectivity/ protecting ecological corridors	Protecting conectivity	Protecting conectivity	Protecting conectivity

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