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The Last Coastal Jaguars of Ecuador: Ecology, Conservation and Management Implications

Miguel Saavedra Mendoza, Paúl Cun,
Eric Horstman, Sonia Carabajo and Juan José Alava

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Abstract

Ecuador is one of the top countries with the highest biodiversity indexes in the planet. Among the mammal species inhabiting tropical forests along Ecuador's coast, wild cats such as ocelots (*Leopardus pardalis*), jaguarundis (*Puma yagouaroundi*), cougars (*Puma concolor*) and jaguars (*Panthera onca*) are a key group of carnivores deserving critical consideration because these species are facing several anthropogenic threats and conservation challenges. Of particular attention is the critically endangered subspecies of jaguar (*Panthera onca centralis*) from the Ecuadorian coast. Despite this species is the largest cat in Ecuador's coastal tropical forests and demanding large territories to survive, little is known about its population and conservation status. In most forests along Ecuador's coast, habitat loss due to deforestation and fragmentation, poaching of prey and illegal hunting threaten the survival of jaguars and questions linger about its ecology and population health. Based on recent field observations using transects and deployment of camera traps, as well as surveys conducted with the local community in and around Cerro Blanco Protected Forest and surrounding areas of the Cordillera Chongón-Colonche Mountain Range, we advance the state of the ecological knowledge of coastal jaguar populations with conservation implications of its threatened habitat and long-term survival in Ecuador.

Keywords: jaguar, *Panthera onca centralis*, population ecology, tropical forests, anthropogenic threats, conservation, Ecuador, South America

1. Introduction

The jaguar (*Panthera onca*) is the largest wild cat of the Americas and the supreme predator of the Amazon River Basin, the largest flooded tropical rain forest in South America. The jaguar

has a broad distribution in the Americas, from the southwest of United States and Mexico, through Central America, to the north of Argentina [1–5]. Because the rates of deforestation are high in Latin America and associated habitat fragmentation have isolated jaguar populations, they are more susceptible to human persecution as well as human competition for jaguar's prey [2, 5]. While the known geographical distribution range and area of occupancy originally occupied by jaguars has currently been reduced by 48–55% in the Americas region in the last century [6], it has been estimated that about 27% of the jaguar range exhibits depleted major wild prey [7].

In Ecuador, this species inhabits the lowlands and foothills of tropical forest and fragmented areas from tropical (i.e., 800–1000 m above mean sea level, AMSL) and subtropical (i.e., from 800 to 1000 m to 1800–2000 m AMSL) regions located to the western and eastern the Andean chain range, respectively [3, 8–13]. Of particular attention is the critically endangered subspecies of jaguar (*Panthera onca centralis*) from western Ecuador inhabiting humid and dry tropical forests still persisting along the coast, mainly in protected areas such as the Cotacachi-Cayapas Ecological Reserve (Esmeraldas province), Machalilla National Park (Manabí province) and Cerro Blanco Protected Forest in Guayas province [14–18]. While the coastal jaguar has been considered to be extirpated from Machalilla National Park [18], where the available habitat for jaguar has been reduced by 80% due to deforestation [8] with the last records being reported about 20 years ago [19], the species stills exist at the north part of the Cotacachi-Cayapas Ecological Reserve [17, 20], as well as in BPCB [14, 16].

The presence of jaguars has recently been confirmed in Cerro Blanco Protected Forest located at the southeast of the “Cordillera” Chongón Colonche Range (i.e. Chongón Colonche Protected Forest) on the central coast of Ecuador [14, 16]. Likewise, the plausible existence of jaguars has been suggested in areas with small woodland remnants around the La Ercilia village, Los Ríos province, on the coast of Ecuador (M. Saavedra-Mendoza, *personal communication*, 2017). Other wild cat species inhabiting forests along Ecuador's coast include the ocelot (*Leopardus pardalis*), oncilla (*Leopardus tigrinus*), margay (*Leopardus wiedii*), jaguarundi (*Puma yagouaroundi*) and puma (*Puma concolor*) [11, 12].

As an emblematic species, the jaguar is a fundamental icon of the ancient cultures and traditional knowledge of aboriginal communities and farmers in Ecuador. The archaeological findings echo that the first records of the jaguar's presence in Ecuador dated back to the artistic manifestations left by the pre-Columbian cultures [8, 13]. The presence of ceramics dating more than 3000 years old clearly represent jaguars, occupying an important place in the cultures of the pre-Columbian Ecuador, where it was worshiped (e.g., “otorongo” in the Antisuyo period: 530–468 B.P.) and represented a symbol of power and connection between men, mother nature and gods [21, 22]. At present, several indigenous tribes (e.g., the Waorani, The Cofán, The Awá) in Ecuador maintain myths and related beliefs with the jaguar [13]. The jaguar was named “El tigre” by Spanish explorers, who recalled the tiger in Asia [1]. Actually, the jaguar has also been identified with “the tiger” in coastal Ecuador by farmers from rural communities for generations due to its alleged similar appearance and ferocity.

While Ecuador is one of the top megadiverse countries with one of the highest biodiversity indexes in the planet [23], deforestation and several other anthropogenic threats such as habitat loss and fragmentation due to urbanization and agriculture, illegal poaching and hunting, mining, oil exploitation, and pollution jeopardize the survival of several tropical mammals [24]. Particularly, the jaguars dwelling in the last remnants of tropical forests along Ecuador's coast are threatened due to several human made threats [15, 16, 18]. Contrasting to the substantial field research invested and dedicated to the subspecies of jaguar from the Amazon basin jungle (*P. onca onca*), little is known on the population and conservation status of coastal jaguars from Ecuador. Despite this species being the largest cat in Ecuador's coastal tropical forests and demanding large territories to survive, questions linger on whether a healthy population of jaguars still remains along the coastal region. In general, Ecuador's wild felines are a key group of carnivores deserving critical consideration because they are facing several environmental stressors and conservation challenges. In this chapter, we review the recent conservation status of coastal jaguars and contribute with new ecological data using as study case the population of the last jaguars inhabiting Cerro Blanco Protected Forest in Ecuador.

2. Materials and methods

2.1. Study area

The study area comprises the tropical forests of Cerro Blanco Protected Forest (BPCB hereafter) and the surrounding areas of the "Cordillera" Chongon-Colonche Range in Guayas province (**Figure 1**). The BPCB total area is 6000 ha and is located at the southern part (last extension) of the "Cordillera" Chongon-Colonche Range, close to Guayaquil City. Based on the floristic inventory the National Herbarium of Ecuador, BPCB possesses five categories of potential natural vegetation: Dry Plain Forest, Dry Rocky Forest, Humid Ravines Forest, Subhumid Plateau Forest, and Subhumid Montane Forest [25, 26]. The Chongon-Colonche Range is a mountain range on the central pacific coast of Ecuador, located in the provinces of Guayas, Santa Elena and Manabí. The Cordillera" Chongon-Colonche Range harbours the Chongón Colonche Protected Forest (≈86,000 ha), which is biogeographically found within the Tumbes-Choco-Magdalena biodiversity hotspot [23, 27] and part of the Chongón Colonche-Machalilla biological corridor, being one of the last remnants of native flora and vegetation in the coast. The forests still remaining in this mountain range contain high levels of biodiversity and was given the category of an Important Bird Area (IBA) [27, 28]. The Chongón Colonche Range is of paramount importance because of the ecological functions and environmental wellbeing and services that it provides to wildlife and local communities. This mountain range harbours high biodiversity and interconnects potential biological corridors for threatened species with wide distribution ranges. In fact, the Chongón-Colonche Range is one of the few coastal regions of Ecuador that still offers potential habitat suitability to big cats, among them the jaguar of the coast, *P. onca centralis* [16].

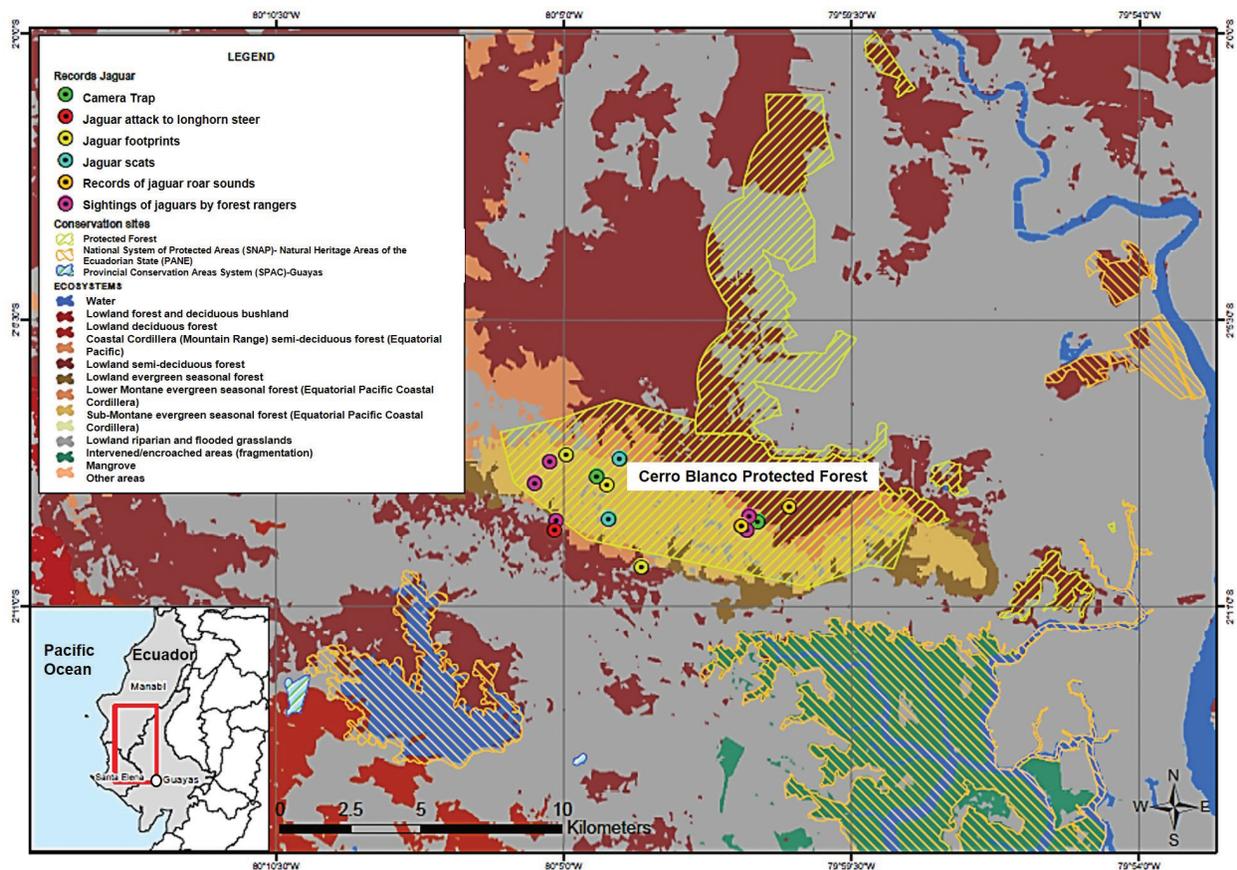


Figure 1. Map illustrating the study area and field observations and records of coastal jaguars (*P. onca centralis*) reported during the sampling and field work along transects as well as rangers encounters in and around the BPCB (area encircled with a white circle in inset map), Guayas Province, Ecuador. The inset map (bottom left corner) displays the Ecuadorian coast (grey area) with the approximate boundaries (red rectangle) of the Cordillera Chongón-Colonche Mountain Range (Guayas, Santa Elena and Manabí provinces) and part of Machalilla National Park (Manabí Province).

2.2. Field sampling and observations

Field sampling and observations were focused on monitoring indirect records following the methods described by Cuesta et al. [29]. Thus, from June 22, 2008, to February 9, 2009, we deployed sampling efforts searching for excrements, footprints, feeding and resting sites. Potential direct observations were considered in sites, where the animals have left their tracks (e.g., footprints), following the methodology by Aranda [30]. Transects and camera trap were deployed in BPCB and surrounding areas of the Chongon-Colonche Mountain Range [16].

2.3. Experimental design and spatial sampling for transects

Five study sites were selected to deploy transects in the BPCB (**Figure 1**), described as follows: (a) transect 1 is characterized by being at a height of about 300 m above mean sea level (AMSL); at this level, it is common to find mist during most of the year with the presence of occasional “garuas” in the dry season (i.e. as reference, the “caseta Pigio” (Pigio guard station) is located very close to the study site); (b) transect 2 is part of a ravine, within which most of its extension is included and surrounded by several other small ravines along its route, converging in it; this

sites usually maintains water during the dry season (i.e. as a reference, its initial point (Point 0) is very close to the “caseta three Bocas” (3 Bocas guard station)); (c) transect 3 extends along a path leading from the installations of the Holcim quarry facilities (i.e., authorized Swiss quarry company to exploit limestone) adjacent to the BPCB towards the “caseta Papagayo” (Papagayo guard station), at 150 m AMSL, and it is a dirt road that is rarely used with several ravines perpendicularly converging along its track; (d) transect 4 extends along a trail that connects the “Papagayo hut” to the “Jaguar Caseta” (Jaguar guard station), starting with a steep slope of about 200 m, followed by a flat trail along all its path; transect 4 altitude is at 300 m AMSL and ends up at a ravine, called “Quebrada Cóndor,” harbouring important remnants of water sources in several sectors; and, (e) transect 5 is a dirt road between the Jaguar and Pigio stations, at about 300 m AMSL. **Table 1** shows the geographical coordinates for transects deployed in BPCB.

The monitoring was conducted along each transect (2 km length) and were marked every 50 m with orange fluorescent tape. The criteria to select transects were mainly based on trails that were rarely used by humans, as well as sectors contiguous to ravines and paths made by native fauna. Furthermore, all sites were selected relying on field information and traditional knowledge from rangers and ancestral users assuring that they have observed feline records in these sites from the forest. The field observations and data collection were conducted during diurnal hours with a total sampling effort of 3 days per transect. In addition, field inspections were carried out at the installations of the Holcim quarry company, located at 2.17°S and 80.06°W, following the invitation of staff members of the environmental department who observed footprints in sites around the quarry. They also provided evidence of past sightings and testimonies of witnesses that complemented the information of presence of jaguars in BPCB.

Transects/stations	Point 0		Point 1000		Point 2000	
	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude
Transect 1 Reference: trail to Pigio station	80.03°W	2.15°S	80.04°W	2.15°S	80.045°W	2.15°S
Transect 2 Reference: Ravine to 3 Bocas station	80.01°W	2.15°S	80.01°W	2.16°S	80.015°W	2.16°S
Transect 3 Reference: Trail to Papagayo station-Holcim	80.07°W	2.17°S	80.08°W	2.17°S	80.08°W	2.16°S
Transect 4 Reference: Trail to Papagayo station-Jaguar station	80.08°W	2.14°S	80.09°W	2.15°S	80.09°W	2.155°S
Transect 5 Reference: Trail to Jaguar station-Pigío station	80.07°W	2.14°S	80.07°W	2.14°S	80.06°W	2.15°S

Table 1. Geographical coordinates and spatial data of transects used in the Cerro Blanco Protected Forest (BPCB).

2.4. Camera trap deployment

Cuddeback digital camera traps were deployed in several sectors along transects at BPCP. This digital device has 3.1 megapixels with daylight and 1.3 megapixels at night (in this period the photographs were in black and white), staying active 24 hours a day. Specifically, a camera trap was installed at a site on a probable jaguar route in the vicinity of a guard stations named “caseta Cusumbo.” The photographic records obtained from larger cats allowed us to identify species and determine the population estimate for jaguar in BPCB by capturing and recapturing individuals through the identification of natural jaguar marks with the methodology proposed elsewhere [31, 32]. Similarly, the photo-records of medium and large mammals were used to determine the tropical fauna and/or potential prey of big cats, including jaguars.

2.5. Surveys with the local community and forest rangers

Interviews, anecdotic communications and traditional knowledge from forest rangers, fishers and residents of BPBP and “Cordillera” Chongón Colonche Range, as well as coastal communities inhabiting villages and towns around the study areas were taking into consideration for this work. This qualitative information was collated from the early 1990s to April 2017.

2.6. Preliminary assessment anthropogenic threats

With the aim to provide a snapshot assessment of the status information on human made impacts affecting the conservation and survival of coastal jaguar from BPCB and “Cordillera” Chongón-Colonche Mountain Range, we compiled the best information available for anthropogenic threats [8, 13, 15, 16], and then we developed a rating scheme based on the authors’ knowledge as well as best technical judgment, as shown in **Table 2**. The ratings indicate as

Rating*	Meaning
	Status, trend, data, and/or actions provide contradictory or inconclusive information. Actions are needed to move into positive status and trend and avoid negative status and trend.
	<ol style="list-style-type: none"> 1. The status of the species was or is healthy according to available data or/and best judgment 2. The population trend is positive if known 3. Some data are available; and/or 4. Actions to address or mitigate impacts are or will be underway and are likely to be potentially effective. Actions should be taken to maintain positive status and/or trend.
	<ol style="list-style-type: none"> 1. Negative Impacts and threats were or are high risk and have resulted in a threatened or endangered status of the species 2. Improvements are uncertain, minor, or slow; and/or 3. Actions to address or mitigate threats or impacts are non-existent, vague, or have low effectiveness. Actions are needed to move into positive status and trend.
	Not rated as there is not enough data to produce an assessment.

*Ratings are qualitative, subjective and are designed to provide the reader with a status at a glance.

Table 2. Scheme assessment for the rating of anthropogenic threats and environmental impacts on coastal jaguars from the BPCB and “Cordillera” Chongón-Colonche Range in Ecuador.

much as about the need for actions related to any threat as well as about the current status of any particular issue.

3. Results and discussion

3.1. Field observations: indirect and direct records

The findings of this research highlight the remarkable presence of a very small population of jaguars ($n = 2$) as revealed by the camera traps, field observations (presence of scats, footprints) and forest ranger personal encounter accounts with jaguars around BPCP and surrounding areas.

3.2. Transects surveys

The monitoring along transects provided a preliminary and effective approach to track the existence of jaguars and confirmed the presence of several species of mammals in the BPCP. On transect 3 at the Candil Creek, feline scats were recorded on 22 September 2008 (**Figure 2A**), while on transect 5 another excreta was identified from the same individual on November 26, 2008. Additional inspections conducted at Holcim mining facilities revealed the presence of footprints from a big cat that often travels through the site, but remains distant from the limestone extraction activity and machinery; which is a human-disturbed sector with the presence of an artificial lagoon/pond (**Figure 2B**). For instance, during the first inspection around Holcim (25 September 2008), foot prints (8–9 cm length; **Figure 2C**) and tracks of a larger cat (**Figure 2D**) were observed without being able to confirm the species (i.e. puma or jaguar although cougars have not been recorded for several years at BPCB) because the footprints were slightly deteriorated due to the soil erosion and dryness; however, machinery operators working at this sector confirmed the observation of a jaguar approximately 4 years earlier and their descriptions of the animal observed agree with the characteristics and colours of the jaguar. In the second inspection (15 December 2008), some tracks (footprint length = 8–9 cm; **Figure 2E**) with a footprint inter-distance of 48 cm from the anterior to posterior footprints (**Figure 2F**) were again observed and likely to be left by a jaguar the day following a light rain on December 13. The indirect records on these locations are fully consistent with indirect observations previously collected in the same sites and contiguous sectors by forest rangers in recent years [16], suggesting that this specific individual uses these trails for daily movements to enter the BPCB.

3.3. Photos from camera traps

From June 2008 to February 2009, the deployment of camera traps generated positive outcomes for the photo-records, allowing to mark recapture at least one jaguar (**Figure 3A–D**). A trap camera captured and confirmed the images of the same jaguar in four occasions in 2008 (i.e. September 12, September 16, November 10 and November 11; as shown in **Figure 3**). The trail used by the photo-identified jaguar coincides with the indirect records reported by rangers and with the excreta collected on 22 September 2008 (**Figure 2A**) in a ravine (“Quebrada Candil”),

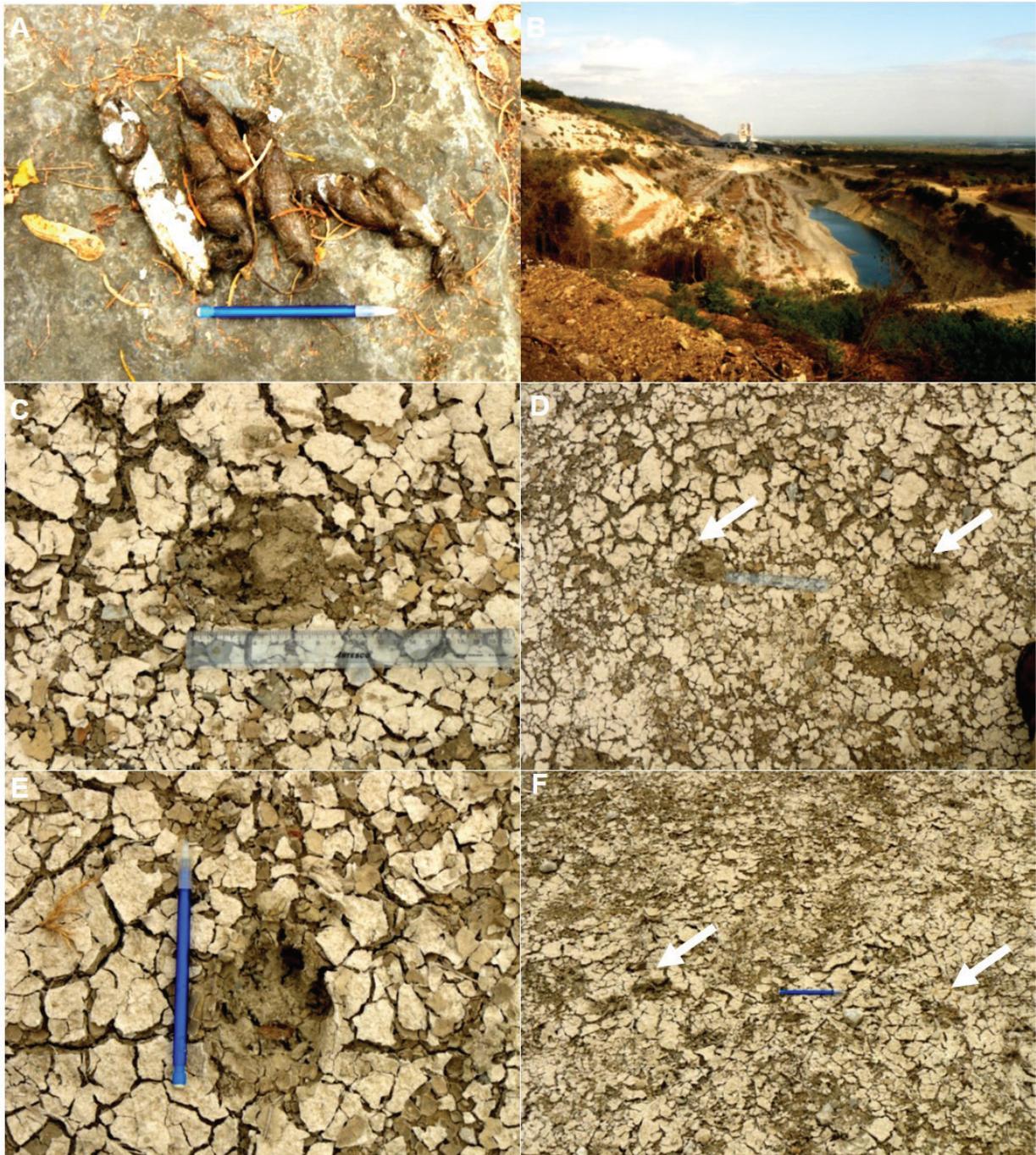


Figure 2. Photos of scats and footprints of a jaguar roaming in and around trails of BPCB. (A) Scats found on transect 3 at the Candil Creek; (B) a photo of the view of the monitored areas at the limestone quarry mine (Holcim installations); (C & D) footprint (8–9 cm) and track (inter-footprint distance = 35–38 cm) recorded on a trail nearby Holcim facilities on 25 September 2008); and, (E & F) additional jaguar's tracks (inter-footprint distance = 43 cm) and footprints (8–9 cm) found in the same site on 15 December 2008. Photos adapted from Ref. [16].

as well as the footprints found around the quarry installations on 25 September 2008 (**Figure 2C** and **D**). In 2011, new images of the same individuals were captured by the camera on April 1, July 12 and July 25 following further field monitoring of the jaguar population at BPCB (**Figure 3E** and **F**).



Figure 3. Camera trap photos of a jaguar mark-captured and recaptured in the study area from 2008 to 2011. The same individual was observed in the following dates in two different sites: (A) 9 September 2008; (B) 16 September 2008; (C) 10 November 2011; (D) 11 November 2011; (E) 01 April 2011; (F) 12 July 2011; and, (G) 25 July 2011. The red and black arrows in photos A-D indicate number and shape of black spots to identify the jaguar. Photos of jaguar captured from 9 September 2008 to 11 November 2008 were adapted from Ref. [16].

3.4. Abundance estimates

Based on the overall field observations, it is estimated that this individual uses 60% of BPCB (approximately 3600 ha) as part of its territory [16]. Conversely, the occurrence of at least one jaguar in the total area of BPCB (i.e. 6000 ha or 60 km²) would imply a density of 1 jaguar per 60 km². This abundance is very similar to the minimum abundance found for this species (1 jaguar per 64 km²) in the Pantanal, Brazil [33]. A population density of 2.63 jaguars/100 km² was estimated at the Cotacachi-Cayapas Ecological Reserve (2500 km², including buffer zone) in northwest Ecuador [17], while a density of 2.25 individuals per 10,000 ha (100 km²) was estimated in Costa Rica [34]. This could demonstrate that the jaguar identified in this study could also include areas within the protected area that are outside the BPCB, and that this area is likely to be a territorial encounter for two individuals, coinciding with the record of a major fighting event or courtship involving two jaguars observed in a ravine near the Jaguar guard station by a forest ranger in 2006 (see **Table 4**).

The field studies on jaguar abundances conducted in Central and South America indicate absolute abundances ranging from 1 to 9 jaguars per 100 km² [17, 32, 35–38]. Assuming that the lower bound of this abundance range (i.e. 1 jaguar/100 km²) can be extrapolated to the total area of the Chongón Colonche Protected Forest (440–700 km²), it is estimated that a plausible abundance of at least 4–7 jaguars would be inhabiting this area. In the Cotacachi-Cayapas Reserve, it is likely that a small population of at least 20–30 jaguars remain there [13]. The projected jaguar conservation units in western Ecuador account for 10% (i.e. 8700 km²) of the original distribution and home range for jaguars, as reported by Espinosa et al. [13], with a potential overall population of less than 250 individuals [15]. However, caution should be taken into account to interpret these estimations as the forest and basin conditions and environmental factors of these regions differ.

3.5. Associated mammalian fauna

Both direct and indirect records observed along transects revealed the presence of several mammalian species part of the tropical fauna found in BPCP (**Table 3**). As shown in **Figure 4**, these observations are further corroborated based on images of mammals captured from camera traps deployed along transects over the study period at BPCB, where mammals such as white-tailed deer, *Odocoileus peruvianus* (**Figure 4A**); crab-eating raccoon, *Procyon cancrivorus* (**Figure 4B**); ocelot, *L. pardalis* (**Figure 4C**); jaguarondi, *Puma yagouaroundi* (**Figure 4D**); Northern tamandua, *T. mexicana* (**Figure 4E**); Central America agouti, *Dasyprocta punctata* (**Figure 4F**); tayra, *Eira barbara* (**Figure 4G**); forest rabbit or tapeti, *Sylvilagus brasiliensis* (**Figure 4H**); and, white-nosed coati, *Nasua narica* (**Figure 4I**) were photo-identified [16]. Relative to the direct observations and indirect records, the camera trap captured images of most terrestrial mammals, except for two common species of monkey, including the Ecuadorian mantled howler monkey (*Alouatta palliata aequatorialis*) and Ecuadorian white-fronted capuchin (*Cebus aequatorialis*), which are arboreal mammals. Most of these mammalian species, including white-tailed deer, collared peccary, agouti and tapetis, can well serve as prey given the broad spectrum diet and opportunistic predatory behaviour of this species [1, 3, 39, 40]; thus, these mammals reflects the available prey community in the region and can be part of the jaguar's prey to sustain a local population in the BPCB. For instance, as part of a Conservation International's

Common name	Latin name	Direct	Indirect	Camera trap
White-tailed deer	<i>Odocoileus peruvianus</i>	P	P	P
Collared peccary	<i>Pecari tajacu</i>	P	P	A*
Crab-eating raccoon	<i>Procyon cancrivorus</i>	P	P	P
Central America agouti	<i>Dasyprocta punctata</i>	P	A	P
Tapeti/forest rabbit	<i>Sylvilagus brasiliensis</i>	P	P	P
Mantled Howler monkey	<i>Alouatta palliata aequatorialis</i>	P	A	A
White-fronted capuchin	<i>Cebus aequatorialis</i>	P	A	A
White-nosed coati	<i>Nasua narica</i>	P	A	P
Northern tamandua	<i>Tamandua mexicana</i>	P	A	P
Coastal jaguar	<i>Panthera onca centralis</i>	A	P	P
Ocelot	<i>Leopardus pardalis</i>	A	P	P
Jaguarondi	<i>Puma yagouaroundi</i>	A	A	P
Tayra	<i>Eira barbara</i>	A	A	P

Adapted from Ref. [16]. P = presence; A = absence.

*A camera trap recently installed at BPCB captured photos of collared peccaries on 24 December 2016 and 6 January 2017.

Table 3. Type of field records and observations for jaguars and associated mammals from 2008 to 2009.

rapid assessment program (RAP) carried out in BPCB, L. Emmons reported the presence of large quantities of bones of deer (i.e. both white-tailed, **Figure 4A**, and red brocket deer, *Mazama americana*, are found in BPCB), indicating the presence of jaguars (E. Horstman, *personal communication*, 2017). Although there are puma (*P. concolor*) in the BPCB, there have been no reported sightings in several years (E. Horstman, *personal communication*, 2017), which may explain the lack of this species in photo-records captured by camera traps.

3.6. Accounts of forest ranger reports and local community testimonies

The recent history of accounts and encounters supporting the existence of jaguars at BPCP started with one of the first confirmed sightings dating back to the early 1990s when the late E. Aspiazu Estrada, then President of the Guayaquil Chapter of Fundación Natura (one of Ecuador's first major environmental organization), observed a jaguar crossing a road below a sightseeing site (known as "Mirador de los Monos") in BPCB (E. Horstman, *personal communication*, 2017). In 1990, the third and fourth authors (E.H. and S.C.) set up a field research and camped nearby this site, but while they did not observed jaguars, they did find large foot prints in the access road near the campsite. In the following years, more tracks on dirt roads, scrapes on trees and occasional scat with soil heaped on the deposit in cat-like fashion have periodically been found (E. Horstman, *personal observations*, 1990s). Several plaster casts have been made of tracks (footprints) and a scat sample was collected. These samples were sent to R. Williams (former country director of the Wildlife Conservation Society), who confirmed that both tracks and the scat were probably jaguar.



Figure 4. Camera trap photos of tropical mammals recorded in the study area from June 2008 to February 2009. (A) White-tailed deer (*O. peruanus*); (B) crab-eating raccoon (*P. cancrivorus*); (C) ocelot (*L. pardalis*); (D) jaguarondi (*P. yagouaroundi*); (E) Northern tamandua (*T. mexicana*); (F) Central America agouti (*D. punctata*); (G) Tayra (*E. barbara*); (H) forest rabbit/tapeti (*S. brasiliensis*); and, (I) white-nosed coati (*N. narica*). Additional deployment of a camera trap in 2016 confirmed the presence of collared peccaries (*P. tajacu*) in BPCB (J). The photo set containing Figures A-I were adapted from Ref. [16].

The data resulting from the accounts by forest rangers and interviewed park guards are reported in **Table 4**. 100% of the interviewed rangers had observed jaguars or/and experienced at least one encounter with jaguars. One of the captivating forest ranger observations is that of the jaguar attack on a longhorn steer (“criollo” breed) that wandered into an area alone near the Papagayo guard station in the BPCB buffer zone in 1996 (**Table 4**). The steer was attacked by a large cat (jaguar) that left deep scratch marks along the side of the neck and flanks. The jaguar had apparently attacked the steer from behind trying to unsuccessfully kill it by biting behind the head.

In 2006, a park guard reported hearing and watching two large jaguars snarling and either fighting or perhaps in courtship in a ravine near the Jaguar guard station. The same park guard that witnessed the attack on the longhorn steer also had a compelling close encounter face to face with a jaguar in 2007 while riding a horse on patrol on the trail linking the Pigio and Cusumbo guard stations. As the ranger came around a bend in the trail, the horse was startled by a jaguar standing in the middle of the trail and reared and tried to buck off the ranger as it ran away. Similarly, a park guard had a close encounter with a jaguar at night at an encampment where forest restoration was being carried out. The ranger went out and

Number	Interviewed people	Site	Account/testimony/comment
1	Forest ranger/park guard: A.M	Papagayo guard station; BPCB buffer zone	In 1996, a longhorn steer was attacked by a jaguar.
2	Forest ranger/park guard: P.O.	Ravine near the Jaguar guard Station	In 2006, two jaguars were heard and seen snarling and fighting or in courtship.
3	Forest ranger/park guard: A.M.	Trail linking the Pigio and Cusumbo Top guard stations	2007, a close encounter with a jaguar on a trail while ranger was horseback riding.
4	Forest ranger/park guard: F. M.	Forest restoration site	Ranger had a jaguar encounter close to encampment site at night
5	Chief forest ranger/park guard: P.Y.	N/A	Anecdotic information and stories about the confirmed presence of jaguar in BPCB.
6	Property owner and workers	Land within north side of BPCB	A female jaguar and a cub were spotted near an artificial water hole.
7	Caretakers of ranch (Hacienda Molino)	Ranch (Hacienda Molino); BPCB buffer zone	Regular sightings of jaguars are made associated with loss of domestic dogs to big cats.
8	Farmer/rancher	Cerro Azul (Monte Sinai)	A pregnant (female) jaguar had been shot and killed. The farmer claimed that he had been supposedly attacked by the jaguar and killed in self-defense. However, this is questionable as there are no reported attacks by jaguars in and around BPCB.*

*Note: This report was originally provided by a past director of the Wildlife Management Program of the former governmental organization INEFAN (Instituto Ecuatoriano Forestal y de Areas Naturales), and corroborated later on by a former Fundación Pro-Bosque employee (N. Zambrano).

Table 4. Qualitative data of interviews and accounts from forest rangers and rural communities around BPCB, BPCB buffer zone and surrounding areas.

illuminated a jaguar with his flashlight and he struck a nearby tree with his machete several times, but the jaguar was unperturbed and slowly turned around and walked away.

Recurrent sightings of jaguars are also made in the BPCB buffer zone, including a nearby ranch “Hacienda El Molino,” where caretakers have reported the periodic loss of domestic dogs to big cats. Of particular importance are two accounts by a farmer and property owner with his workers from the rural community in and around BPCB as they reported female jaguars either pregnant or with a cub, respectively (**Table 4**). These reports suggest that reproduction for this species may be feasible within a breeding ground in the BPCB.

In general, throughout the development of surveys and exchange of information to search for evidences of the species presence and encounters with members of communities, most of the interviewed persons were likely to confirm the existence of the jaguar, commonly called “tiger” because of their black spots and the similarity that they have noticed by the old films or movies, showing its ferocity at attacking people [16]. Thus, a general “fear factor” has been attributed to this species by the rural community without knowing it.

Meanwhile, the information collected from our surveys with the rangers and rural community partially diverge from the opinion from local residents of Machalilla National Park, where there are mixed perceptions about the presence of jaguar, i.e. some people argued that the jaguars disappeared 20 years ago, while others suggested they still inhabit isolated areas of the park [18].

3.7. Anthropogenic threats

A preliminary assessment of anthropogenic impacts and environmental stressors on coastal jaguars in Ecuador’s mainland coast, focused on the BPCB and “Cordillera” Chongón Colonche Range, is shown in **Table 5**. This evaluation scheme reflects a qualitative effort to further advance our understanding of past, present and future impacts and threats jeopardizing the long-term survival of jaguars. The hunting of jaguar for the skin trade and habitat loss by population growth and urbanization, deforestation and mining have been among the most critical impacts negatively affecting jaguar populations in Ecuador [8, 14–16]. Because of the jaguar’s large size (i.e. the largest among the New World felids) and the beauty of its skin, this species was and is still one of the most persecuted and hunted mammals by indigenous people, military, farmers, settlers or poachers in the Ecuadorian territory [8, 13, 15]. Conversely, the jaguars are persecuted in many livestock and farming areas as they can sometimes kill cattle and domestic animals or for the fear of the local people to be attacked. At the BPCB and “Cordillera” Chongón Colonche hills, there are only historical anecdotes among the rural community that the species is a threat to this activity, which must be further corroborated. However, the reported isolated jaguar attack on a longhorn steer in 2006 and the presumably attack to a farmer at BPCB (**Table 4**) warrant the need of further research.

Western and Tumbesian forests of Ecuador have been logged and deforested by timber exploitation, farming and ranching, with less than 5% of the original forest coverage remaining by the 1990s [27, 41, 42]. As a result, the extent and degree of deforestation and forest land converted to farms and livestock have proportionally reduced habitat suitability for coastal jaguars in recent times (**Table 5**). Efforts to reforest and rehabilitate areas previously cleared out are underway through forest restoration program at BPCB. While mining for extraction of limestone from

Threats/impacts	Past	Current	Future
Habitat loss and deforestation	(1)	(2)	*(biological corridors implementation is uncertain)
Hunting and illegal traffic	(1)	(3)	*(it could follow the same trend as in Current assessment)
Jaguar's prey poaching and hunting	(1)	(2)	*(it could follow the same trend as in Current assessment)
Mining	(1)	(2)	(4)
Livestock	(1)	(4)	(4)
Pollution of River Basins	(1)	(3)	*(implementation of pollution control and command regulations is uncertain)
Introduced species	(1)	(2)	*(some invasive plant species (e.g., <i>Panicum maximum</i>) are controlled within BPCB, but it is unknown whether eradication would take place outside of BPCB and buffer zone)
Diseases	Lack of data	Lack of data	Lack of data
Climate change	(1)	(3)	(3)**

See **Table 2** for definition of colour and rating meanings, as aforementioned.

Remarks:

(Red: 1): Negative impacts and/or threats were or are high risk and have resulted in an endangered status of the species.

(Red: 2): Improvements are uncertain, minor, or slow.

(Red: 3): Actions to address or mitigate threats or impacts are non-existent, vague, or have low effectiveness. Actions are needed to move into positive status and trend. (Red: 3**): The looming desertification in areas with prolonged droughts may cause severe impacts on jaguar's habitat and prey availability in the future. Actions are needed to move into positive status and trend.

(Blue: 1): The status of the forest ecosystem was healthy according to available data (see references [27, 41]) and best available knowledge and judgment from researchers and natural resource managers.

(Blue: 4): Actions to address or mitigate impacts are or will be underway and are likely to be potentially effective (i.e., abandonment and restoration plan following closure of quarry mining and presence of livestock is low).

*Status, trend, data, and/or actions provide contradictory or inconclusive information. Actions are needed to avoid negative status and trend.

Table 5. Snapshot assessment of anthropogenic threats for coastal jaguars in Ecuador's mainland coast focused on the BPCB and "Cordillera" Chongon-Colonche Range.

the BPCB has evidently fragmented and disturbed habitat for jaguars residing in the forests the BPCB and "Cordillera" Chongón Colonche range, the species still persists there although in very low numbers, as documented in this study and elsewhere [16]. It is expected that ecological restoration under an abandonment and environmental management plan will be implemented following the closure of the quarry in the final phase of the project (**Table 5**).

3.8. Current legislation and management actions to conserve jaguars in Ecuador

In Ecuador, the environmental and wildlife legislation to manage and protect jaguars emerged in 1970 when a government decree considered the jaguar as a species of limited hunting under certain regulations of the Ecuadorian state (Official Register No. 818; November 20, 1970), but jaguar hunting was fully banned later on by the Ecuadorian government when the

state ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Official Register No. 746; February 20, 1975) [15]. Recently, the Ministry of the Environment, through Resolution No. 105, promulgated a law prohibiting hunting of jaguars in the Ecuadorian territory, indefinitely (Official Register No. 5; January 28, 2000). The jaguar's original distribution also overlaps important natural areas protected by the National System of Protected Areas of Ecuador's Minister of Environment. Internationally, The IUCN considers the jaguar to be a Near-Threatened species (NT) [5], while in Ecuador the population of coastal jaguar is considered as critically endangered (CR) [15]. As a signatory country of CITES, the jaguar is listed in Appendix I (<https://cites.org/eng/gallery/species/mammal/jaguar.html>), prohibiting any commercial activity, including live animals, dead or any of its parts or organs (i.e., jaguar paws, teeth and other products) in Ecuador.

As for our study area, Cerro Blanco Protected Forest (BPCB) was created and managed by the Pro-Bosque Foundation, a private and non-profit organization established under Ministerial Agreement by the Ministry of Agriculture and Livestock, on November 9 (1992), to protect and restore the forest and its river basin. Therefore, by protecting the forest remnants and basin of BPCB, suitable habitat for jaguars and their prey can be conserved in the long-term. Similarly, the "Cordillera" Chongón-Colonche Mountain Range was declared Protected Forest in 1994 with the aim of achieving conservation of the pre-mountain Humid Forest and Tropical Dry Forest [43]. Since 1998, forest plantations have been fostered under different systems in the protected forest's buffer zone, as a management strategy to counteract the extraction of wood/timber [43].

In addition, the jaguar is included under the category of threatened species by the Environmental Management Ordinance of the Provincial Council of Guayas Province, involving the protection of threatened (or endangered) species with the aim of recovering its population stability. Likewise, the Municipality of Guayaquil passed the Environmental Policies of the Municipality of Guayaquil, in which the jaguar is considered a native species of tropical dry forests and thus included in policy 4.5, involving the recovery of this species.

3.9. Conservation implications

The indirect records of jaguar, ranger encounters and the photo-identified individual inhabiting the protected tropical forest (i.e. BPCB) and surrounding areas of the "Cordillera" Chongón-Colonche Mountain Range provide strong evidence of jaguar in our study region. The individuals found here face different degrees of anthropogenic impacts and fragmentation [16]. Moreover, in the face of lack of additional information available to manage this species, the findings and theoretical estimates of plausible abundance provided here can be used as a guide and premise to support decision makings and policy aimed to foster *in situ* conservation and proactive management actions for the species, following the precautionary principle. Because jaguars still remaining in these threatened regions show resilience and adaptation to human perturbations, conservation initiatives and adaptive management actions should consider the region as high priority jaguar conservation unit to preserve one of the last jaguar populations of the Ecuadorian coast. The inclusion of private landowner and ranch owners in jaguar conservation programs with proactive conservation actions for jaguars' habitat and potential corridors for their dispersal within critical habitats may promote

long-term population viability by functionally adding private land and ranches to reserve size within jaguar conservation units [44–47]. To achieve this community-based conservation level, proactive relationships between ranchers and authorities must be established to maintain effective agreements [47]. Moreover, because of the small population size, isolation, defective protections and escalating human population, future conservation efforts by Red List assessments' assessors can be prioritized for the most threatened subpopulations of jaguars as an imperative subject of urgency [6]. Thus, contrasting to the "low priority conservation unit" attributed to the habitat of coastal jaguars in the Cotacachi-Cayapas, Cordillera Chongón-Colonche and BPCB [13], we strongly argue that these regions are one of the most important areas and critical habitats of most urgent conservation concern to protect the long-term survival of coastal jaguar subpopulations.

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Author details

Miguel Saavedra Mendoza¹, Paúl Cun², Eric Horstman², Sonia Carabajo² and Juan José Alava^{3,4,5*}

*Address all correspondence to: jalavasa@sfu.ca

1 Urbanización Paraíso del Río, Guayaquil, Ecuador

2 Fundación Pro-Bosque, Bosque Protector Cerro Blanco, Guayaquil, Ecuador

3 School of Resource and Environmental Management, Simon Fraser University, Burnaby, British Columbia, Canada

4 Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, British Columbia, Canada

5 Coastal Ocean Research Institute, Vancouver Aquarium Marine Science Centre, Vancouver, British Columbia, Canada

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