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Spectacled bears surrounded by gold mines in the Serranía de San Lucas, Colombia

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Abstract: The spectacled bear (*Tremarctos ornatus*) is one of the most threatened large mammals in Latin America. Using camera traps from 2021 to 2022, we sought to investigate the status of the species in the Serranía de San Lucas (San Lucas), an isolated and unprotected mountain range in northern Colombia. We calculated a relative abundance index of spectacled bears, evaluated spatial overlap between their distribution and gold mining, and estimated deforestation in San Lucas. During 2,749 trap-nights, we recorded 24 detections of spectacled bears at an average elevation of 1,070 m \pm 307 standard deviation. Detections were recorded from 8 of the 30 camera-trap locations, corresponding to ≥ 4 individual adult bears, including 2 females with cubs. Gold mining concessions overlap approximately 21% of the species' range in San Lucas, which experienced a 13.4% decrease in forest cover between 2001 and 2021. Gold extraction poses significant challenges for spectacled bear conservation in northern Colombia.

Resumen: El oso de anteojos (*Tremarctos ornatus*) es uno de los grandes mamíferos más amenazados de América Latina. Utilizando cámaras trampa en 2021–2022, buscamos investigar el estado de la especie en la Serranía de San Lucas (San Lucas), una formación montañosa aislada y desprotegida en el norte de Colombia. Calculamos un índice de abundancia relativa de osos de anteojos, evaluamos la superposición espacial entre su distribución y la minería de oro, y estimamos la deforestación en San Lucas. Durante 2.749 noches trampas, registramos 24 detecciones de osos de anteojos a una elevación promedio de 1.070 metros \pm 307 DE. La especie fue detectada en 8 de las 32 ubicaciones de las cámaras trampa. Estos registros corresponden a al menos 4 individuos adultos,

incluidas 2 hembras con cachorros. Las concesiones mineras de oro cubren aproximadamente el 21% del área de distribución de la especie en San Lucas. Esta última experimentó una disminución del 13,4% en la cobertura forestal entre 2001 y 2021. La extracción de oro plantea importantes desafíos para la conservación del oso de anteojos en el norte de Colombia.

Key words: camera traps, Colombia, deforestation, gold mining, human disturbances, spectacled bear, *Tremarctos ornatus*, Tropical Andes

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Endemic to the Tropical Andes, the spectacled bear (*Tremarctos ornatus*) is the only extant bear species in South America (Vela-Vargas et al. 2021). In Colombia, the species' range is estimated to cover $\sim 59,492$ km² across a broad elevational gradient from 200 to 4,250 m (Velez-Liendo and García-Rangel 2017). Spectacled bears exhibit a preference for cloud forests and alpine meadows and high-altitude grasslands known as Páramos (Peyton 1980, Cuesta et al. 2003). These habitats in the Colombian Andes are the core of the species' range in the country despite containing $\sim 76\%$ of its human population and undergoing rapid transformation (Kattan et al. 2004, Madriñán et al. 2013, DANE 2020, Etter et al. 2020). As a result of the threats of habitat loss and fragmentation, poaching, and climate change, both the International Union for the Conservation of Nature (IUCN) and the Colombian government categorize spectacled bears as 'Vulnerable' (Velez-Liendo and García-Rangel 2017, MADS 2017).

In Colombia, spectacled bear research exhibits considerable geographic bias, with most in-situ studies occurring in a few national parks encompassing high-elevation Páramos (Vela-Vargas et al. 2021). Despite considerable refinements in range delineations of the species over the past decade (Rodríguez et al. 2019), there are still many regions in Colombia where the status of spectacled bears remains unassessed (Rodríguez 2015). The Serranía de San Lucas (hereafter, San Lucas), one of South America's most urgent conservation priorities (Salaman et al. 2001, Andrade et al. 2011, Bonell-Rojas 2018), is one such region.

Tropical forests of northern Colombia have experienced extensive deforestation—with almost complete

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Table 1. Sampling effort, naïve occupancy (Ψ), and spectacled bear (*Tremarctos ornatus*) photographs obtained from camera traps in 3 elevation zones in the Serranía de San Lucas, Colombia, 2021–2022.

Zone	Elevation range (m)	No. cameras ^a (no. with bear detections)	Naïve Ψ ^b	No. trap-nights	No. indep. ^c bear photos	RAI ^d
High	1,298–1,687	11 (1)	0.09	1,065	2	0.19
Mid	930–1,258	11 (5)	0.45	784	11	1.28
Low	541–761	8 (2)	0.25	900	11	1.22
Total	N/A	30 (8)	0.26	2,749	24	N/A

^a35 camera traps were installed but 3 were stolen and 2 malfunctioned.

^bNaïve Ψ (% of camera traps with spectacled bear detections).

^cSpectacled bear detections were considered independent if ≥ 60 min separated photographs taken at the same camera-trap location.

^dRelative abundance index, calculated as the number of detection events (photographic captures) per 100 days of sampling effort.

forest clearance in the floodplains and foothills of the river valleys (Etter et al. 2020)—but San Lucas represents the largest block of intact forest in the middle Magdalena River basin. At varying points over the past decade, a national park was proposed for San Lucas but numerous socio-economic complications halted protected area declaration and the region remains entirely unprotected (Parques Nacionales Naturales de Colombia 2021). Intensive and largely unregulated mining currently operates to the extent that towns in southern San Lucas have some of the highest mercury levels in the world (Cordy et al. 2011).

Decades of armed conflict and social instability, now both closely linked with mining (Betancur-Corredor et al. 2018), have long impeded scientific investigations in San Lucas where the conservation status of large mammals remains unknown. Following surveys that targeted collection of baseline data on this group, we report records of spectacled bears in San Lucas in the context of extensive gold mining in the region.

Study area

Spanning $\sim 10,959$ km² of tropical and subtropical moist broadleaf forest in northern Colombia, San Lucas is an isolated massif ranging from 200 to 2,250 m above sea level (m.a.s.l.), elevations at which Páramo ecosystems do not occur. With 27,691 inhabitants, Santa Rosa del Sur is the most populous municipality in San Lucas (DANE 2020).

Mean annual precipitation in the region varies between 2,500 and 2,800 mm, with most rainfall occurring from April to May and September to November. There is a distinct dry season from December to February, during which precipitation

averages < 130 mm/month. January is the driest month and October is the wettest.

Material and methods

Camera-trapping

We conducted camera-trap surveys from April 2021 to July 2022. Each sampling point had a single, unbaited camera trap (Reconyx model HC600, HF2X, or XR6; Reconyx Inc., Holmen, Wisconsin). Camera traps were placed at 35 sampling points within 3 sites, each in a distinct elevation zone (Table 1). Our study area spanned an elevational gradient of 541–1,687 m.a.s.l.

In each zone, the average spacing between camera traps was 1.2 km (range = 0.8–2.1 km). All camera traps were placed ~ 45 cm above ground level on trees bordering trails. To facilitate identification of individual bears, we programmed camera traps to record a 3-image burst when triggered.

Data analysis

Upon retrieval of camera-trap photos, we calculated a relative abundance index (RAI) as follows:

$$RAI_i = n_{tot} / nights_{tot} \times 100$$

where n_{tot} is the number of independent photographic events of spectacled bears and $nights_{tot}$ is the total number of camera-trap-nights (TN). Spectacled bear detections were considered independent if photographs taken at the same camera-trap location were separated by ≥ 60 minutes. This time threshold, commonly used in camera-trap studies (O'Connell et al. 2011), enables circumvention of inflated counts caused by repeated detections of the same event (e.g., a curious bear sniffing a camera trap over a 5-min period). We also calculated naïve occupancy Ψ

probabilities, defined as the proportion of total camera traps where the bears were detected.

To better understand the status of spectacled bears and their habitat in San Lucas, we calculated forest loss and evaluated threats of gold mining in the region because the two are often linked (Sonter et al. 2017, González-González et al. 2021). For estimating overlap between the spectacled bear's IUCN distribution and the gold mining concessions, we used the geo-algorithm “intersect” in ArcGIS Pro v. 10.8.1 (ESRI Inc., Redlands, California). We obtained the distribution of gold mining concessions from Colombia's Sistema de Información Minero Colombiano (SIMCO 2020) and we downloaded the spectacled bear distribution data from the IUCN Red List (Velez-Liendo and García-Rangel 2017).

For the deforestation analysis, we used the Analyze and Track Forest Change tool in Global Forest Watch (<https://www.globalforestwatch.org/>) to quantify, at a spatial resolution of 30 m, the following: (1) The percentage of San Lucas covered by forest in the year 2000 (defined as pixels with >30% tree canopy cover; Hansen et al. 2013); (2) The proportion of these forested areas corresponding to primary forests in 2000, defined as mature natural humid tropical forest cover that has “not been completely cleared and regrown in recent history” (Turubanova et al. 2018:1); and (3) Total and primary forest change from 2001 to 2021. We completed the forest change analysis using the forest loss and forest gain layers described in Hansen et al. (2013).

Results

Data were obtained from 30 of the camera-trap locations (3 camera traps were stolen and 2 malfunctioned; Table 1). Total sampling effort from the camera traps was 2,749 trap-nights (TN; Table 1). Primarily as a result of permission issues, cameras were not operational simultaneously for the full 16-month period between the start and end of the surveys; rather, they were active for an average of $148 \text{ TN} \pm 95$ standard deviation (SD) at each sampling point. We recorded 24 detections of spectacled bears at 8 of the 30 camera traps at a rate of 0.87 photographic ‘captures’/100 TN (Fig. 1; Table 1). The average elevation of detections was $1,070 \text{ m} \pm 307$ SD. Based on analysis of their distinct facial markings, we identified 4 adult bears and 2 cubs (Fig. 2).

Our analysis revealed that 736 km^2 (21%) of the spectacled bear's IUCN distribution in San Lucas is overlapped by gold mining concessions. The average

size of these concessions is $8.20 \text{ km}^2 (\pm 43.10 \text{ km}^2 \text{ SD})$. All our spectacled bear records were either inside or within 10 km of a gold mining concession.

In the year 2000, 94% ($10,289 \text{ km}^2$) of San Lucas was covered by forest, with primary forest comprising 70% ($7,157 \text{ km}^2$) of this forested area. Between 2001 and 2021, 14% ($1,438 \text{ km}^2$) of the forest cover was lost, with 56% (801 km^2) of this loss corresponding to primary forest (Fig. 3). During this same period, forest gains spanned 58 km^2 . Punctuated by a distinct peak in 2017—immediately following Colombia's 2016 Peace Accord—forest loss appears to be increasing over time (Fig. 3).

Discussion

Our study presents new information on the occurrence of, and threats to, spectacled bears in San Lucas. Despite their status as flagship and umbrella species (Crespo-Gascón and Guerrero-Casado 2019), very few studies have documented spectacled bears outside protected areas in Colombia (Parques Nacionales Naturales de Colombia and Wildlife Conservation Society 2018). Even fewer have reported the species' presence in habitats at elevations below 1,000 m, an important research gap considering the widespread habitat contractions projected in Páramos (Cresso et al. 2020). As an indicator of extremely limited biological explorations in San Lucas, irrefutable presence of spectacled bears in the region was not confirmed until 2011 (Vela-Vargas et al. 2014). The next records of the species were not collected in the region until 2018 when surveys obtained 3 camera-trap records (Bonell-Rojas 2018). Most recently, in the dry season of January 2020, a cattle rancher filmed a female bear with 2 cubs at an elevation of 550 m.a.s.l. in Segovia, Antioquia province, a heavily fragmented area in southwestern San Lucas (Cárdenas 2020).

Although our records represent the first verifiable camera-trap photographs of a breeding spectacled bear population in San Lucas, there were some limitations in our sampling. Lack of collaboration from private landowners prevented our ability to survey parts of our originally planned study area. Unanticipated permission issues dictated that we remove some camera traps, which are viewed with unusual suspicion by rural people in San Lucas (J.J. Figel, personal observation). These limitations aside, we provide new insights into the species' seasonal habitat use within a wider landscape where the species' favored Páramo ecosystems are entirely absent.

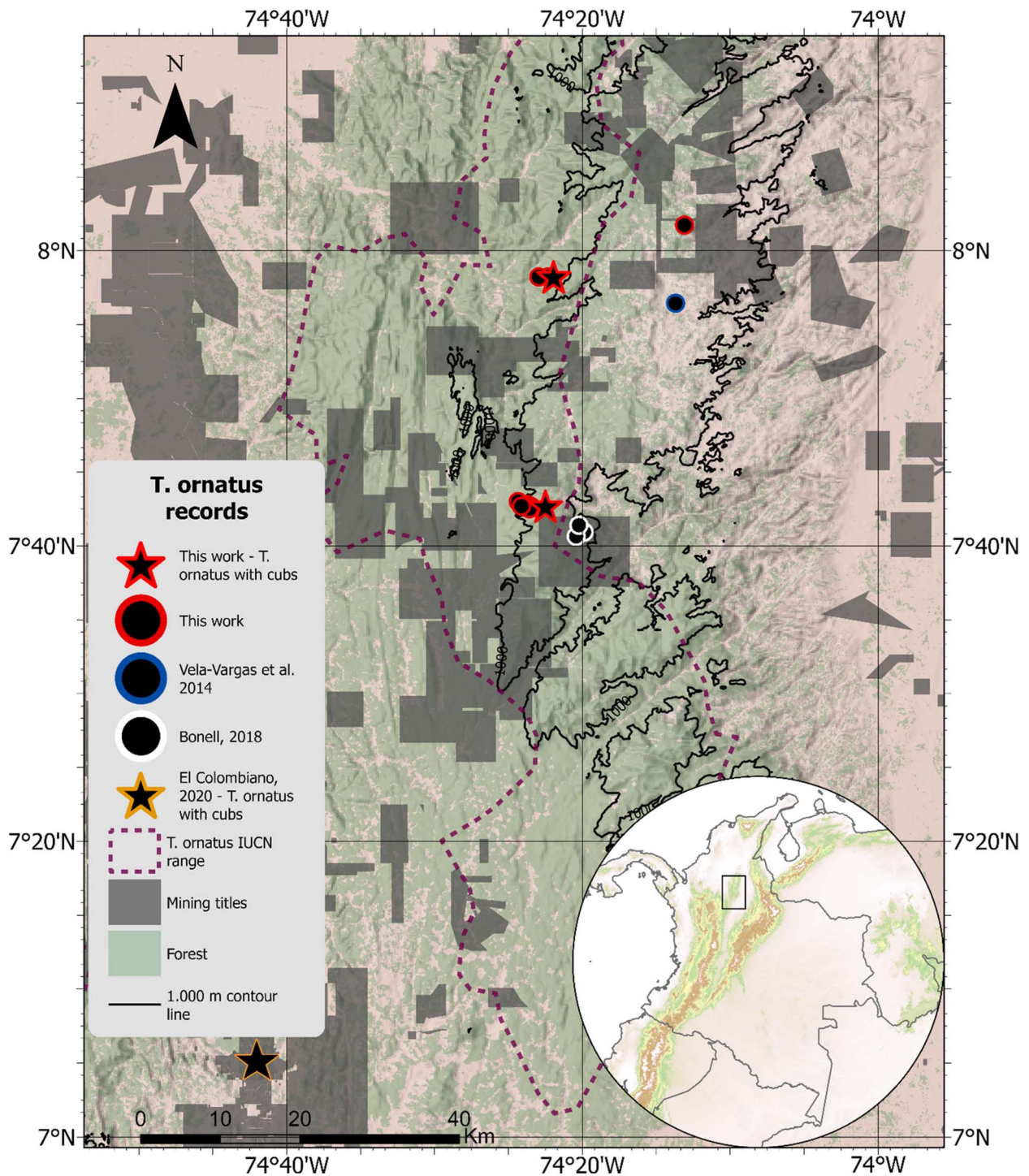


Fig. 1. Spectacled bear (*Tremarctos ornatus*) records, forest cover, and gold mining concessions in the Serranía de San Lucas, Colombia.



Fig. 2. Two distinct spectacled bears (*Tremarctos ornatus*) recorded during camera-trap surveys from April 2021 to July 2022 at elevations of 1,093 and 1,132 m above sea level in the Serranía de San Lucas, Colombia. Note the lack of forehead facial markings in the individual on the left.

In San Lucas, it remains unclear whether spectacled bears are responding to seasonal differences in food availability or variation in human disturbances. The species seasonally migrates in habitats across its range with areas at lower elevations known to provide the bears access to important food resources available only at

certain times of the year (Peyton 1980, Suarez 1988, Cuesta et al. 2003, Castellanos 2011). In the Ecuadorian Andes, spectacled bears exhibited the greatest sensitivity to human disturbances among 8 carnivore focal species (Zapata-Ríos and Branch 2018). And in northern Peru, in one of the few range-wide camera-trap surveys

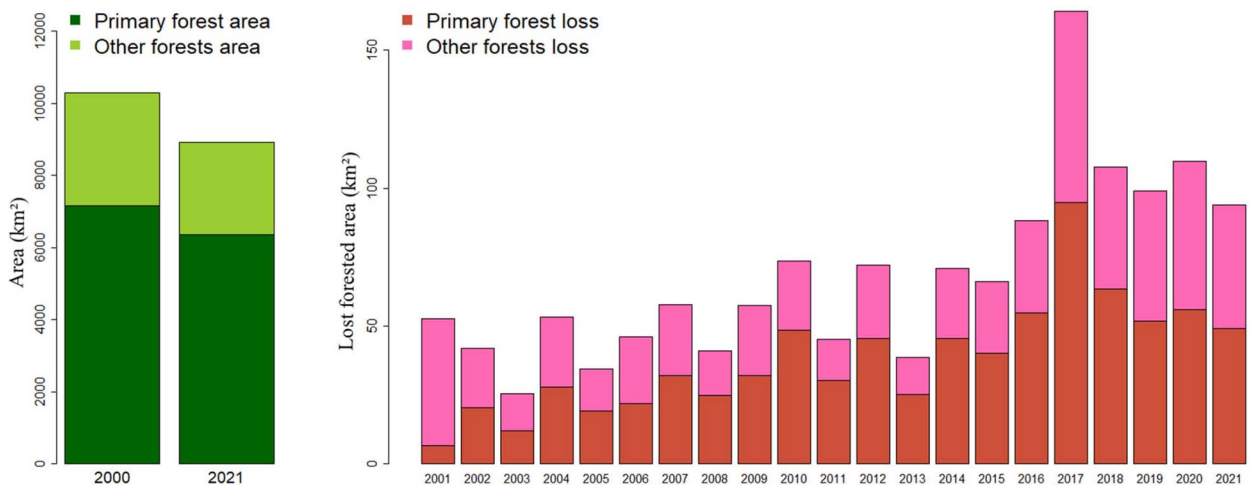


Fig. 3. Forest loss in the Serranía de San Lucas, Colombia, 2001–2021.

sampling the species in unprotected areas <1,300 m.a.s.l., 20 individual bears were recorded during 5,087 TN in a study area without gold mining but with a road system that significantly reduced bear densities (Morrell et al. 2021). Thus, expanding gold mining concessions—which already overlap 21% of the spectacled bear’s range in San Lucas—could disrupt movements and restrict seasonal access to essential habitats along these elevational gradients. Mercury exposure may not be as imminent of a risk to the omnivorous spectacled bear, although the biomagnification of this pollutant should be monitored because it was detected in hunted jaguars (*Panthera onca*) in an adjacent mountain range (Racero-Casarrubia et al. 2012).

The most urgent threat to spectacled bears in San Lucas, according to our deforestation analysis, is widespread habitat transformation that occurs, in large part, from mining activities. The 13.4% net forest loss between 2001 and 2021 is striking and places San Lucas among the most threatened natural areas in the country (Etter et al. 2020). The deforestation spike in 2017, followed by elevated rates of forest loss in subsequent years, is consistent with national trends showing increased deforestation following the 2016 peace agreement (Clerici et al. 2020). Indeed, San Lucas was an area entirely off-limits to biologists until very recently on account of the pervasive presence of violent armed groups (Richani 2013). Although the conflict inhibited natural resource extraction by outside actors, San Lucas remains a region characterized by complex socio-political conditions that complicate the planning and execution of wildlife studies.

Extensive gold mining and associated infrastructure present major threats to spectacled bears in San Lucas. Despite widespread recognition of the biological significance of San Lucas, projected surges in metal mining are likely to necessitate further concession development in the region (Betancur-Corredor et al. 2018, Luckeneder et al. 2021). Although some of these concessions are currently inactive, they are still subject to exploration activities, which attract human migration, road development, and settlement (Sontter et al. 2017). The infrastructure network accompanying these mines poses serious threats to bears in the form of habitat loss, human–wildlife conflict risk, and bioaccumulation of toxic substances (Cristescu et al. 2016, Roy et al. 2018). To mitigate the industry’s most deleterious impacts, we

recommend increased focus on the identification of spectacled bear populations—and the habitats that support their persistence—in mining landscapes. These habitats, in turn, could serve as key corridors connecting the spectacled bear conservation units proposed in national action plans (Parques Nacionales Naturales de Colombia and Wildlife Conservation Society 2018).

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