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COMMENTARY

Howler Monkey Die-Off in Southern Mexico

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ABSTRACT

In May and June 2024, a die-off of Mexican mantled howler monkeys (*Alouatta palliata mexicana*) occurred in southern Mexico. This commentary documents the event, attributing it to extreme heatwaves, drought, wildfires, and habitat impoverishment. Despite their reported resilience to habitat disturbances, mantled howler monkey mortality rate in some areas reached 31%. Key evidence points to heatstroke as the primary cause of death, exacerbated by limited hydration and reduced dietary diversity in disturbed habitats. Immediate responses included community-led rescues (e.g., hydrating the monkeys), coordination of rescue activities by non-governmental organizations (NGOs) (e.g., managing donations), involvement of scientists (e.g., monitoring of primate populations), and assistance from government officials (e.g., providing legal support for animal management). This event underscores the urgency of developing action plans to prevent and attend future crises. Among other actions, we highlight (i) establishing primate care infrastructure with medical and rehabilitation centers; (ii) developing protocols and training programs to ensure rapid crisis response; (iii) fostering collaboration among government, NGOs, and academic institutions for effective crisis management; and (iv) developing targeted research on climate change impacts, predictive models, and long-term health monitoring. We emphasize the critical need for coordinated conservation efforts to protect wild primates and maintain natural ecosystem resilience in the face of escalating climate challenges.

Abbreviations: COBIUS A.C., Conservación de la Biodiversidad del Usumacinta A.C.; IUCN, International Union for the Conservation of Nature; NGO, nongovernmental organization; PROFEPA, Federal Attorney General's Office for Environmental Protection; SEMARNAT, Secretary of the Environment and Natural Resources.

Summary

- In May and June 2024, over 300 howler monkeys died in southern Mexico.
- Key evidence points to heatstroke as the primary cause of death, exacerbated by limited hydration and reduced dietary diversity in disturbed habitats.
- This event highlights the critical need for coordinated conservation efforts to protect wild primates in the face of escalating climate challenges.

1 | Introduction

Animal die-offs are events in which numerous animals die suddenly and simultaneously, often within a specific area or population. Nonhuman primate (hereafter primates) die-offs have been documented in several species, usually resulting from disease (Bermejo et al. 2006; Caillaud et al. 2006) or from the direct (Li et al. 2009) or indirect (i.e., mediated by food shortages: Gould, Sussman, and Sauther 1999; Milton and Giacalone 2014; Waite et al. 2007) effects of extreme weather. Despite their well-documented ability to survive in highly disturbed areas (Arroyo-Rodríguez and Dias 2010; Bicca-Marques, Chaves, & Hass 2020), howler monkeys (*Alouatta*) are also vulnerable to disease and extreme weather. Yellow fever epizootics have historically decimated howler monkey populations (e.g., Almeida et al. 2012; Collias and Southwick 1952; Possamai et al. 2020; Rifakis et al. 2006). Hurricanes that directly impact areas inhabited by howler monkeys also have the potential to cause high mortality (Pavelka et al. 2003). Here, we describe the die-off of Mexican mantled howler monkeys (*Alouatta palliata mexicana*) living in southern Mexico in May and June 2024. In contrast to previous mass mortality events reported for the genus, this die-off was not related to either disease or hurricanes. In this commentary, we describe the context and characteristics of this die-off to document the event and, most importantly, to share our experiences in responding to an emergency for which we, primatologists, were not prepared. Ultimately, our main objective is to raise public awareness of the urgency of developing conservation and management plans that can be implemented during emergencies.

1.1 | Mexican Primates

Three primate taxa occur in southern Mexico: Geoffroy's spider monkeys (*Ateles geoffroyi*; Figure 1A), black howler monkeys (*Alouatta pigra*; Figure 1B), and Mexican mantled howler monkeys (*Alouatta palliata mexicana*; Figure 1C). Mexican mantled howler monkeys are distributed exclusively in Mexico, whereas black howler monkeys are also present in Belize and Guatemala. Geoffroy's spider monkeys are found from Mexico to Panama (Cortés-Ortiz, Rylands, and Mittermeier 2015).

Primates living in Mexico are exclusively arboreal and thus are highly vulnerable to forest loss and degradation (Arroyo-Rodríguez and Dias 2010; Ramos-Fernández and Wallace 2008). From 2001 to 2023, over 4,000,000 ha of forest were lost in Mexico, of which 19% correspond to primary rainforest (Global Forest Watch 2024; Figure 1D). Approximately 70% of the deforested area corresponded to the conversion of forests into pasturelands (CONAFOR 2024). In the State of Tabasco, only 3% of the original vegetation remains. Additional threats to

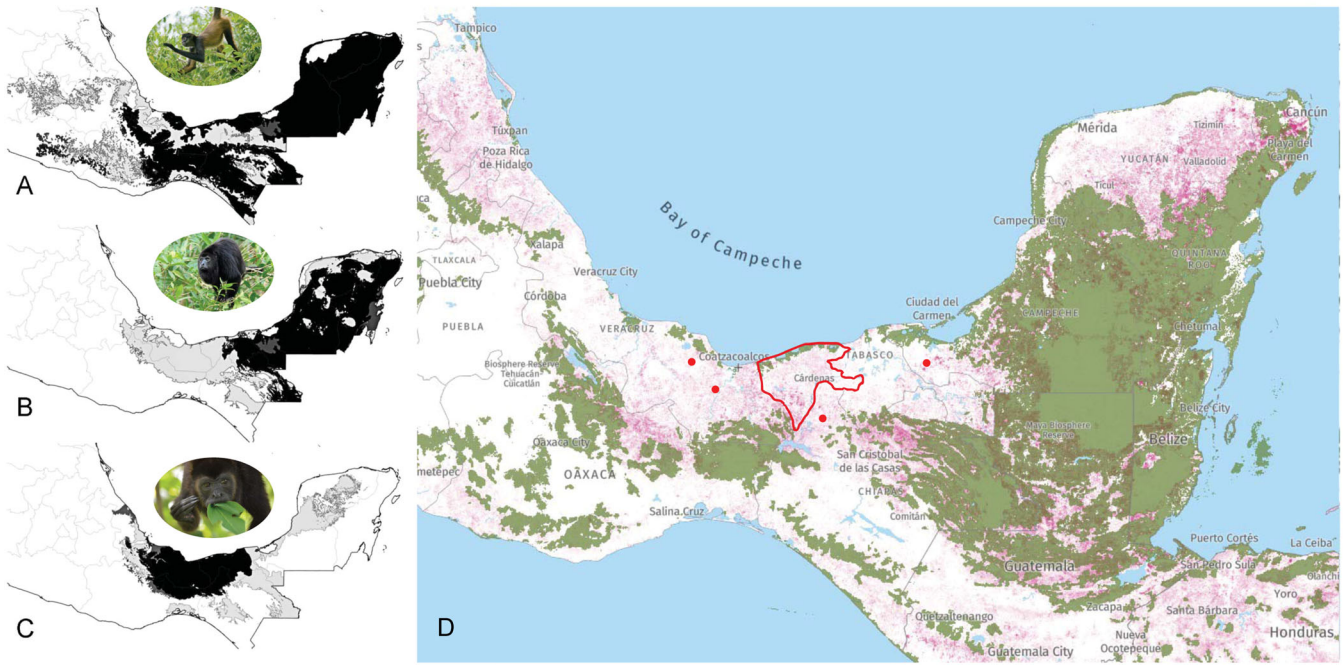

FIGURE 1 | Primate distribution (black polygons) in Mexico: (A) Geoffroy's spider monkeys, (B) black howler monkeys, and (C) Mexican mantled howler monkeys (modified from Calixto-Pérez et al. 2018). In (D) primary forest (green) and forest loss between 2001 and 2023 (pink) are depicted. The red polygon in D corresponds to the Chontalpa region of Tabasco, where most reported deaths occurred during the die-off, and the red dots represent other areas where howler monkey deaths were reported between May and June 2024. The Chontalpa region encompasses five municipalities and extends over approximately 7600 km^2.

these primates include climate change, wildfires, mining, illegal trade, and pollutants (Alvarez-Velazquez et al. 2024; Dias and Rangel-Negrín 2022; Vásquez-Aguilar, Hernández-Rodríguez, and Martínez-Mota 2024). The three taxa are classified as Endangered under the Mexican law (SEMARNAT 2010) and the International Union for the Conservation of Nature (IUCN) Red List (IUCN 2024).

2 | The Die-Off

2.1 | Description

Members of the nongovernmental organization (NGO) Conservación de la Biodiversidad del Usumacinta A.C. (COBIUS A.C.) working in the Chontalpa region of the State of Tabasco (Figure 1D) found two mantled howler monkeys dead on the ground in a cocoa plantation on May 5, 2024. Over the following days, local community members reported observations of monkeys on the ground, dead and alive; reports of monkeys requiring assistance accumulated quickly (Supporting Information S1: Figure S1). By the end of that week, 19 dead monkeys had been found throughout the Chontalpa region, and the number of deaths peaked to a total of 80 individuals in the following week (May 12–18; Figure 2). The last dead monkey was recorded on June 23, following a week without any reported deaths. No other deaths have been reported in the area since.

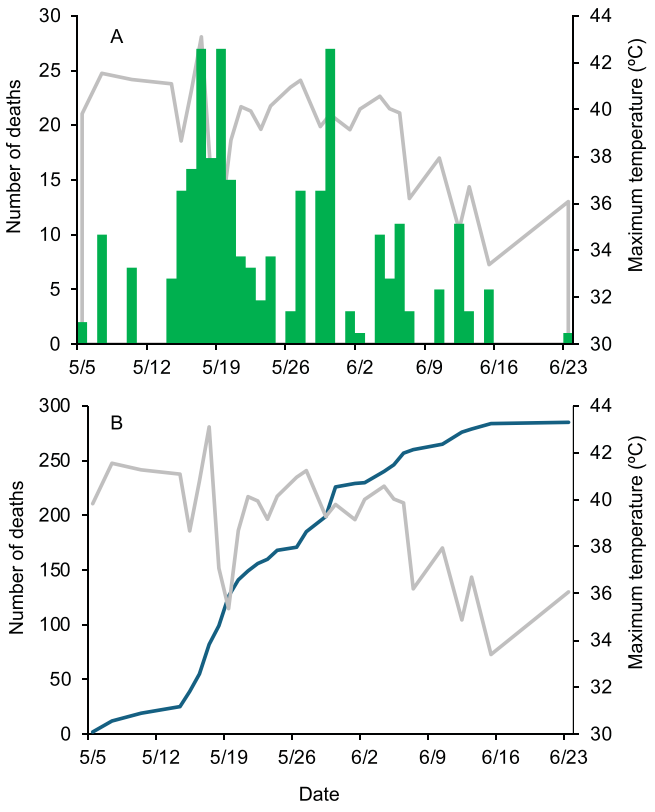

FIGURE 2 | The number of mantled howler monkey deaths per day from May 5 to June 23, total (A, green bars) and accumulated (B, blue line). Maximum ambient temperature is depicted in both panels in gray (right *y* axis).

Overall, we recorded 286 mantled howler monkey carcasses in Tabasco over 50 days. Considering that during surveys conducted in the area between May 5 and June 29, we recorded 635 living individuals, a crude estimate of mantled howler monkey mortality in the Chontalpa region is 31% (Table 1). It is noteworthy that very few infants and juveniles (i.e., individuals between 0 and 14 months and between 15 and 29 months old, respectively: Balcells & Baró 2009) died ($n = 6$), and several infants were found clinging to dead females on the ground. Those infants ($n = 9$) were rescued and taken to a temporary nursery installed in the Cunduacán Municipality (see below), where they were attended with intensive veterinary care. They were later transferred to a facility of the SEMARNAT (Secretary of the Environment and Natural Resources) for rehabilitation. Thirty-two individuals received medical attention, of which 14 were released in their original habitat (Supporting Information S1: Figures S2 and S3), nine were infants currently under rehabilitation, one black howler monkey infant was transferred to a private reserve in Chiapas (Wildlife Conservation Management Unit [UMA] Los Susurros), four are in captivity in the YumKa zoo (Tabasco), and four died. Sixty-four additional deaths were reported in other states during the same period: Chiapas (37 individuals), Veracruz (24), and Campeche (3). Two deaths in Chiapas and all deaths from Campeche corresponded to black howler monkeys.

2.2 | Probable Causes of Death

Heatstroke results from an imbalance between heat production and dissipation and often leads to multiple organ dysfunction. During a heatstroke, complex pathophysiological changes occur due to the direct cytotoxic effects of heat and the acute-phase response triggered by endotoxins, inflammatory cytokines, and chemokines (Epstein and Yanovich 2019). This process involves the activation of endothelial cells, coagulation factors, and fibrinolysis, causing microvascular thrombosis, hypoxia, and organ dysfunction (Schlader, Davis, and Bouchama 2022). Evidence suggests that mantled howler monkey deaths resulted from the consequences of heatstroke and heat exhaustion combined with the poor health status of the monkeys.

First, deaths were concentrated during a period with several heatwaves lasting for 2–4 days (Figure 3). In 2024, under the influence of a strong El Niño-Southern Oscillation event, heatwaves were extreme following a severe drought in mid-2023 (SMN 2024). The intensity of heatwaves was further exacerbated by the occurrence of several wildfires, mostly related to slash-and-burn agricultural practices (CONABIO 2024).

Second, several individuals were found alive on the ground with severe myopathy, including muscle spasms, stiffness, lameness, and tumbling when walking. These symptoms are typical of heatstroke (Epstein and Yanovich 2019). Complete necropsies were performed on nine adults and one infant (eight individuals from Tabasco and one from Veracruz) approximately 12 h after they died (Supporting Information S1: Figure S4). This ruled out the most obvious causes of death, including physical trauma, infectious diseases, or extreme parasitosis. Regarding the latter,

TABLE 1 | Age-sex class of mantled howler monkeys surveyed in the Chontalpa area of Tabasco, Mexico.

Age-sex class	Alive	Dead	Total
Adult females	229	15	244
Adult males	103	20	123
Adults (unknown sex)[a]	20	40	60
Juveniles	108	0	108
Infants	108	6	114
Undetermined[b]	67	205	272
Total	635	286	921

[a]Unknown sex refers to individuals who were recognized as adults by their body size but for which decomposition did not allow conclusive sex determination based on the observation of genitals.
[b]Undetermined refers to individuals who could not be recognized as adults or immatures due to decomposition.

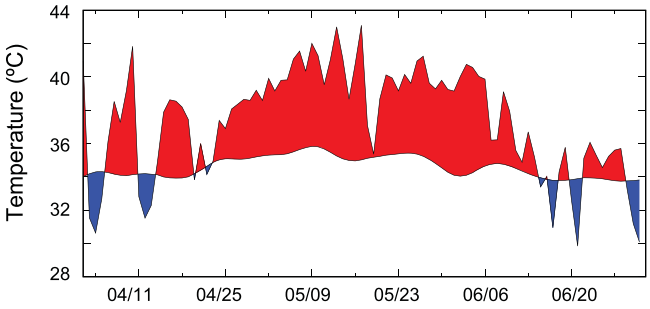

FIGURE 3 | Ambient temperature in the Chontalpa region in May and June of 2024, depicted as the deviation from the mean historical values for the period 1993–2023. Above-average values are illustrated as red polygons and below-average values are in blue (data from the Suomi NPP satellite).

there was no evidence of *Ehrlichia canis* (canine ehrlichiosis), *Dirofilaria immitis* (heartworm), *Borrelia burgdorferi* (Lyme borreliosis), *Anaplasma phagocytophilum* (anaplasmosis), encephalitis, and yellow fever infection. Postmortem analyses revealed signs that are compatible with the pathophysiology of heatstroke, including multiorgan damage with hemorrhaging and necrosis in the lungs, liver, kidneys, and brain. In two individuals who lived in an area where there was a severe fire, there was evidence of heat-induced burns and congestion, and edema in the lungs and heart. Additionally, in four individuals hematologic and biochemical analysis indicated further signs of kidney failure, such as hyperazotemia, hyperphosphatemia, hyponatremia, and hemoconcentration-associated erythrocytosis. Heat exhaustion may have complicated renal damage and pre-existing liver disease in some individuals, who could not cope with multiple stressors (i.e., excessive heat, poor nutrition, lack of hydration, and physical exhaustion; Sejian et al. 2018). Finally, we observed a lot of mucus in a couple of adult males that were still in the trees, along with visible breathing impairments (Supporting Information S1: Figure S5). It is thus possible that not all affected individuals died, and some may still have sequelae that may impact their fitness and longevity.

Most deaths occurred in small (< 20 ha) cacao (*Theobroma cacao*) plantations which also contain scattered trees of several other species (e.g., *Ceiba pentandra*, *Ficus* spp.). Mantled howler monkeys do not use cacao as a food source (Dias and Rangel-Negrín 2015) and rely on the resources available from other plants. However, compared to other forest fragments, cacao plantations are characterized by low tree abundance, low species diversity, with vegetation dominated by fewer tree species, and mantled howler monkeys exhibit lower dietary diversity (e.g., Muñoz et al. 2006). Consequently, individuals living in those agroecosystems likely faced several challenges to their survival before the heatwaves of May and June. Furthermore, howler monkeys mostly hydrate via water contained in food and water produced during metabolism (Dias et al. 2014). Given the desiccation of the vegetation due to drought and excessive heat (Choat et al. 2018), it is likely that in small fragments, where tree abundance is lower, individuals were not meeting their hydration requirements via food consumption.

2.3 | Actors and Actions During the Die-Off

From the onset of the die-off, the first respondents were the people living near the primates, who called authorities for support, and directly cared for the monkeys by trying to hydrate and feed individuals who were on the ground and taking those still alive to veterinary clinics. At the institutional level, in Tabasco, COBIUS A.C. deployed all personnel to attend to the emergency and perform a variety of tasks, including search and rescue of monkeys that were on the ground, providing materials to communities living near primates to support them (e.g., buckets and ropes to place water sources on the trees; Supporting Information S1: Figures S6 and S7), and gathering public awareness about the problem of ongoing fires, and informing people about what to do if they found monkeys in distress (e.g., via infographics and social media posts).

At the government level, local and state authorities were involved in rescuing activities from day one of the crisis. Personnel from Tabasco's office of the Federal Attorney General's Office for Environmental Protection (PROFEPA) provided the necessary legal support to handle the rescued animals, as in Mexico mantled howler monkeys are a protected species, meaning that they cannot be captured, transported, or kept in captivity without the corresponding permits. The authorities from Comalcalco and Cunduacán municipalities made several efforts early on to support the work of rescuers, with the latter providing facilities in the interior structure of the city's baseball field for COBIUS A.C. to install a temporary rescue center where medical attention was given to rescued animals and donations were collected (Supporting Information S1: Figures S8–S10).

Concurrently, in the context of the heatwave affecting the country, reports of primates falling from trees due to extreme heat quickly caught the attention of the public and the media. As a result, people from the entire country mobilized to support the rescue efforts, either by making donations (financial and materials) or by traveling to the area to help. The volunteering of veterinarians was noteworthy, with some 20 professionals traveling to Tabasco from different states and many more showing their willingness to go (Supporting Information S1: Figure S11). Zoos also promptly offered their support through

advice in terms of medical management of the animals but also by sending in-kind donations and trained personnel to support rescue activities (e.g., Zoológico Guadalajara).

The Mexican primatological community came together to support the rescue activities in several ways. Primatologists were in the field searching for animals and surveying populations, as well as providing medical attention to animals in need both in the field and in clinics (Supporting Information S1: Figure S12). Out of the field, they were very active in supporting field-based efforts and the crisis in general by advising, fundraising, disseminating information, and lobbying. For instance, a petition for support published on the Change.org platform (https://bit.ly/4cWbJbG) received over 23,000 signatures, and a letter addressed to the President of Mexico was prepared and signed by more than 20 primatologists requesting the die-off to be proclaimed an *ecological emergency*, as defined in the General Law of Ecological Balance and Environmental Protection (Ley General del Equilibrio Ecológico y la Protección al Ambiente); unfortunately our request was disregarded.

3 | Ways Forward

The die-off of mantled howler monkeys in Tabasco's Chontalpa region underscores the urgent need for comprehensive strategies to prevent future crises. This event highlights the vulnerability of primates to extreme weather and the need for immediate, coordinated action across multiple sectors. Three critical steps include developing infrastructure, protocols, and human resources; enhancing stakeholder preparedness; and identifying pivotal research areas.

First, establishing primate care infrastructure in the region is crucial. This should include a medical unit and a rehabilitation center to address primate casualties from die-offs, electrocution, road accidents, and illegal trafficking. The development of robust protocols and training programs is essential. Protocols should ensure rapid, effective responses to crises with a multidisciplinary team of veterinarians, conservationists, local authorities, and community members (Bicca-Marques and de Freitas 2010). Training programs must equip individuals to identify early signs of distress, provide care, and efficiently manage rescue operations (e.g., Reading, Kenny, and Fitzgerald 2013). Additionally, workshops should be implemented to train local authorities and NGOs in crisis management, creating a network of trained volunteers and professionals ready for rapid mobilization.

Second, crisis management requires the concerted efforts of multiple actors, including government agencies, NGOs, academic institutions, and local communities (Kleiman and Mallinson 1998). Government agencies at all levels must collaborate to develop and enforce wildlife protection policies, create emergency response plans, and provide necessary funding. The federal government should lead these efforts, ensuring resources are available and feedback from experts is incorporated into decision-making processes. NGOs play a crucial role in engaging communities, raising awareness, and mobilizing resources (Shanee and Shanee 2009). Universities and research institutions contribute by conducting studies that inform crisis management and conservation strategies.

Third, targeted research, supported by intersectoral collaboration, is vital for improving crisis management. Government bodies, academic institutions, NGO's and private stakeholders must collectively prioritize key research areas such as the impact of climate change on primate health, and investigating how changing climate patterns, particularly increasing temperatures and extreme weather events, affect the health and behavior of primates. This research should focus on identifying the physiological thresholds of primates and how they cope with heat stress. Habitat management and restoration is another critical area, and therefore studying the effects of habitat loss and degradation on primate populations is fundamental. Research should aim to develop effective habitat management and restoration strategies that can mitigate the impacts of environmental changes, such as habitat loss and degradation, increasing temperatures and increasing frequency and intensity of extreme weather events. Additionally, developing predictive models and early warning systems to forecast extreme weather events and their potential impact on wildlife is crucial. These systems can help in preemptive planning and timely interventions to prevent mass mortality events. Establishing long-term health monitoring programs for primate populations to detect early signs of distress and disease outbreaks is also necessary. Such programs should use advanced technologies like remote sensing and bio-monitoring to collect real-time data (e.g., Rzucidlo, Curry, and Shero 2023). Finally, the role of local communities in wildlife conservation and how traditional knowledge should be integrated into modern conservation practices. Engaging communities in research, conservation, and management actions will be critical to fostering their commitment to protecting wildlife and their habitats (Estrada et al. 2022).

In conclusion, the die-off of mantled howler monkeys in southern Mexico highlights the critical need for comprehensive strategies to prevent future crises. Typically regarded as highly resilient to habitat disturbance, howler monkeys have shown us that their resilience threshold can be surpassed in the context of synergistic interactions of extreme weather, life in degraded habitats, and wildfires. Developing infrastructure and robust protocols, enhancing stakeholder preparedness, better governance, and prioritizing targeted research can significantly improve Mexico's crisis response in the future. We expect that this commentary will serve as a useful resource for primatologists working with species facing similar challenges, offering insights on the ways forward to protect primate populations and conserving the tropical ecosystems they inhabit.

Author Contributions

Gilberto Pozo-Montuy: conceptualization (equal); data curation (equal); formal analysis (equal); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); resources (equal); writing–original draft (equal). **María del Socorro Aguilar-Cucurachi:** investigation (equal); writing–review and editing (equal). **Filippo Aureli:** investigation (equal); writing–review and editing (equal). **Margarita Briseño-Jaramillo:** Investigation (equal); writing–review and editing (equal). **Domingo Canales-Espinosa:**

investigation (equal); writing–review and editing (equal). **Anaid Cárdenas-Navarrete:** investigation (equal); writing–review and editing (equal). **Liliana Cortés-Ortiz:** investigation (equal); writing–review and editing (equal). **Fabiola Carolina Espinosa-Gómez:** formal analysis (equal); investigation (equal); resources (equal); writing–original draft (equal). **Montserrat Franquesa-Soler:** investigation (equal); writing–review and editing (equal). **Candelaria García-Duran:** investigation (equal); writing–review and editing (equal). **Yuliana García-Ojeda:** investigation (equal); writing–review and editing (equal). **Mónica Rosario González-Acosta:** investigation (equal); writing–review and editing (equal). **Javier Hermida-Lagunes:** investigation (equal); methodology (equal); resources (equal); writing–review and editing (equal). **Laura Teresa Hernández-Salazar:** investigation (equal); writing–review and editing (equal). **Cristina Jasso-del Toro:** investigation (equal); writing–review and editing (equal). **José Alberto Lizama-Hernández:** investigation (equal); writing–review and editing (equal). **Ileana Zorhaya Martínez-Ramos:** investigation (equal); writing–review and editing (equal). **Edgar J. Montejo-Zetina:** investigation (equal); writing–review and editing (equal). **Guadalupe Núñez-Martínez:** investigation (equal); writing–review and editing (equal). **Paulina Y. Nuñez-Ramírez:** investigation (equal); writing–review and editing (equal). **Pedro Shautamai Pareja-Badillo:** investigation (equal); writing–review and editing (equal). **Braulio Pinacho-Guendulain:** data curation (equal); investigation (equal); writing–review and editing (equal). **Gabriel Ramos-Fernández:** investigation (equal); writing–review and editing (equal). **Alix Fernanda Rivera-Sánchez:** formal analysis (equal); investigation (equal); writing–review and editing (equal). **Elizabeth Sánchez-Domínguez:** investigation (equal); writing–review and editing (equal). **Juan Carlos Serio-Silva:** investigation (equal); writing–review and editing (equal). **Sandra E. Smith-Aguilar:** investigation (equal); writing–review and editing (equal). **Brenda Solórzano-García:** data curation (equal); investigation (equal); writing–review and editing (equal). **Denise Spaan:** investigation (equal); writing–review and editing (equal). **Sarie Van Belle:** investigation (equal); writing–review and editing (equal). **Pedro A. D. Dias:** conceptualization (equal); formal analysis (equal); visualization (equal); writing–original draft (equal).

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Ethics Statement

This study adhered to the ASP Code of Best Practices in Field Primatology and to the ASP Principles for the Ethical Treatment of Nonhuman Primates. The research followed the legal requirements of Mexican law.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data associated with this article is presented in Table 1.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supplementary Materials for

Howler monkey die-off in southern Mexico

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Figure S1. Mantled howler monkey deaths in Comalcalco, Tabasco.

Figure S2. Fully recovered individuals were released into their original habitat.

Figure S3. Adult female with infant ready for release.

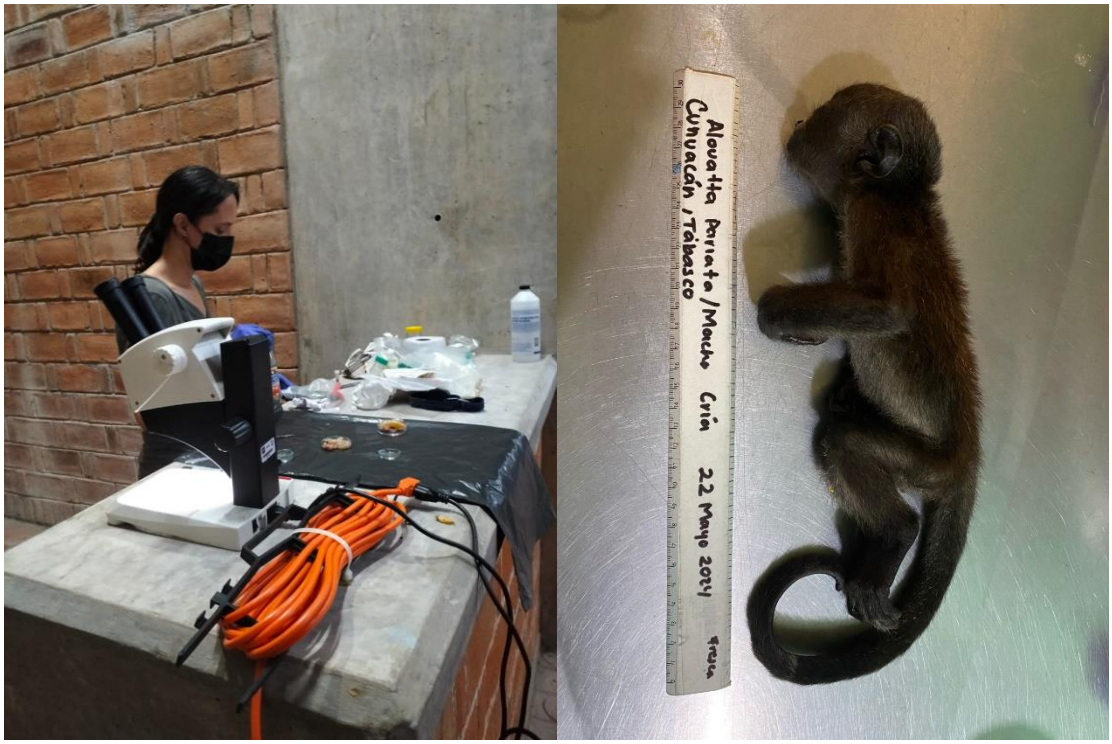

Figure S4. Necropsies were performed and samples were taken for molecular, histopathological, and parasitological analysis.

Figure S5. During the census, sick animals were discovered with abundant mucus.

Figure S6. The death of adult females left several orphaned infants who were rescued by people from local communities.

Figure S7. Brigades were set up to bring hydration to the surviving monkeys with the help of the local communities.

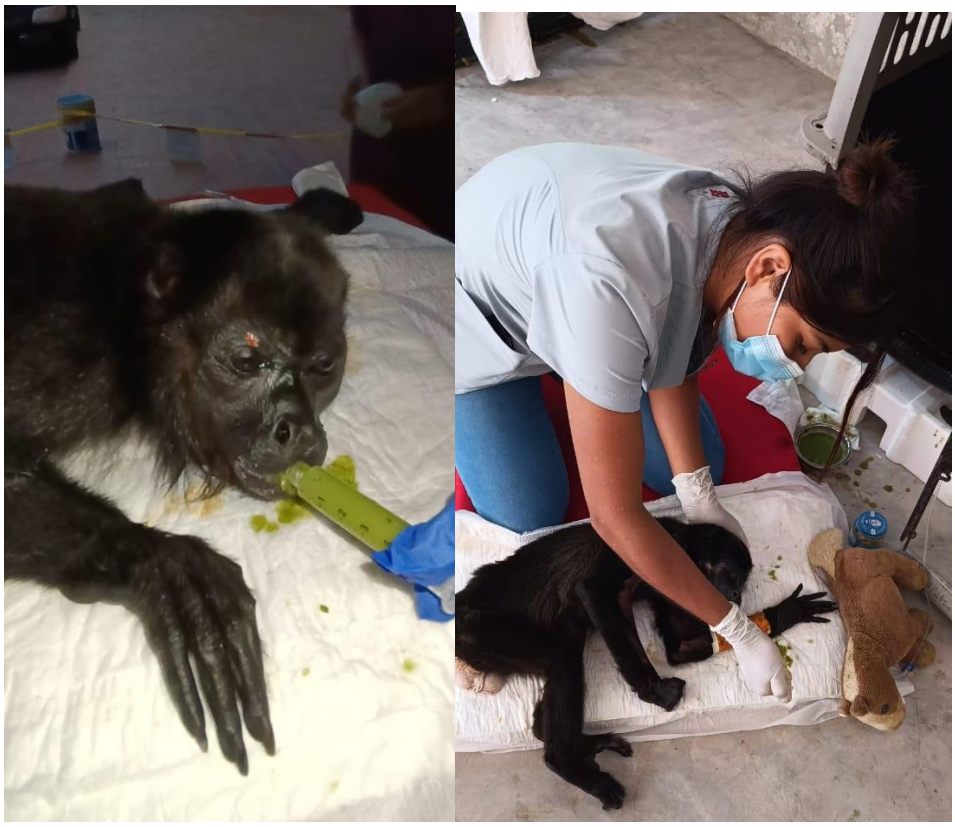

Figure S8. Clinical care protocols were established for adults who moved from intensive care to recovery.

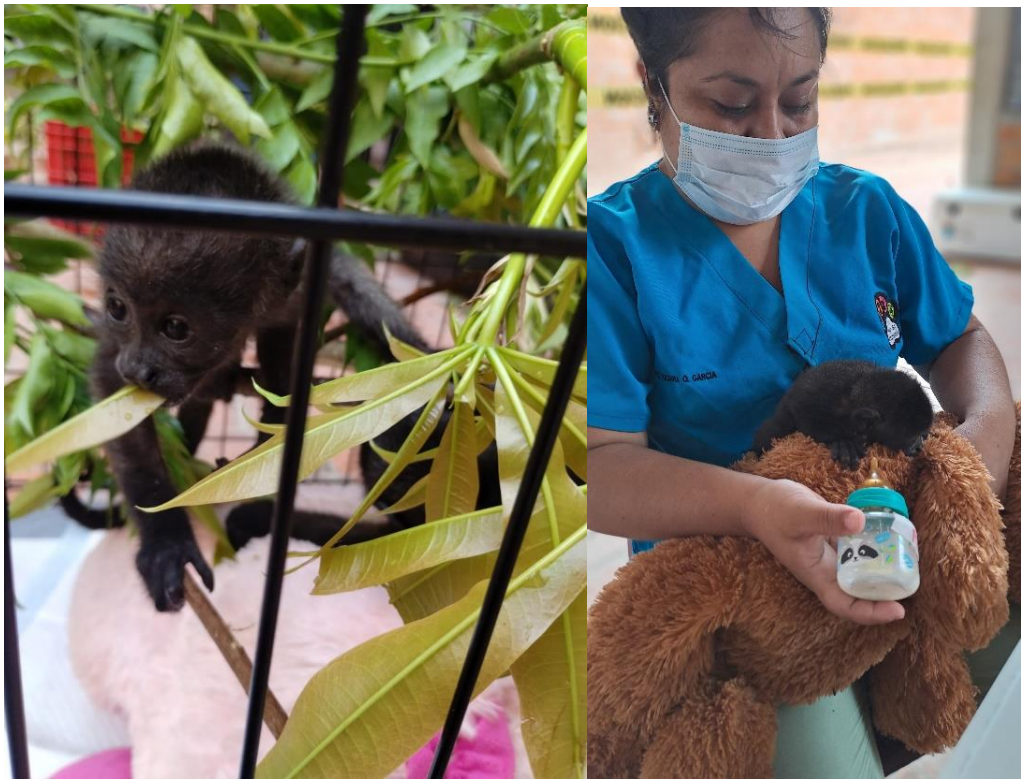

Figure S9. Clinical care protocols were established for infants under a rehabilitation scheme for reintroduction purposes.

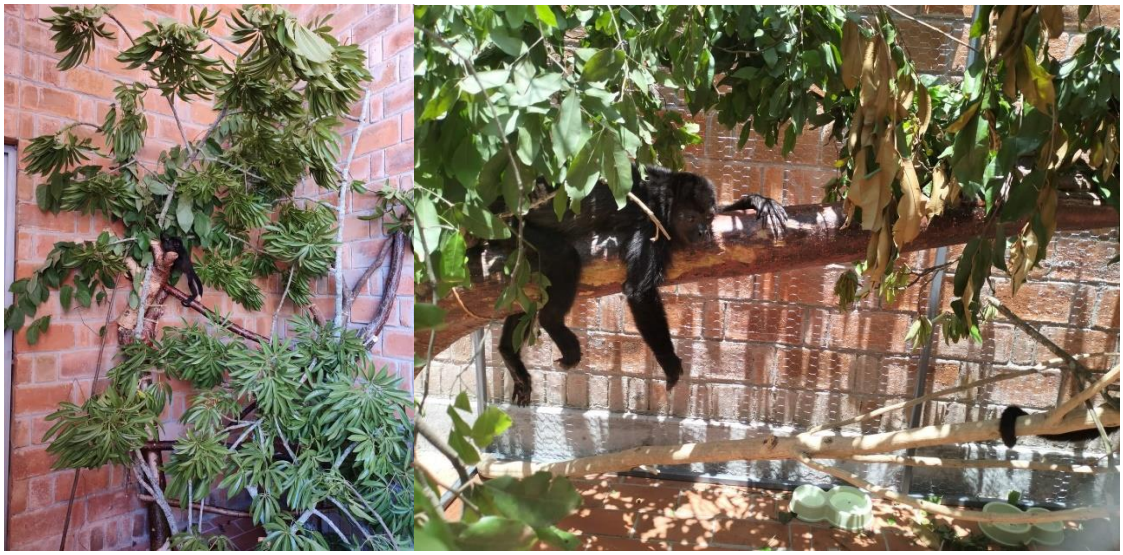

Figure S10. Adults and infants underwent a motor rehabilitation process. Appropriate enclosures were created for this purpose.

Figure S11. COBIUS A.C. established a Medical Attention Unit with the support of veterinarians from different parts of the country.

Figure S12. Brigades of primatologists were assembled to conduct a complete census of live and dead monkeys.