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**ADMISSIONS OF SLOTHS (*BRADYPUS VARIEGATUS* AND *CHOLOEPUS  
HOFFMANNI*) IN COSTA RICAN RESCUE CENTERS (2012–2022):  
SPATIO-TEMPORAL PATTERNS, THREATS, SURVIVAL OUTCOMES, AND  
CONSERVATION IMPLICATIONS**

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Tesis sometida a consideración del Tribunal Examinador del Posgrado en Medicina de la Conservación, para optar al grado de Magister Scientiae en Medicina de la Conservación con énfasis en Salud Ecosistémica. ADMISSIONS OF SLOTHS (*BRADYPUS VARIEGATUS* AND *CHOLOEPUS HOFFMANNI*) IN COSTA RICAN RESCUE CENTERS (2012–2022): SPATIO-TEMPORAL PATTERNS, THREATS, SURVIVAL OUTCOMES, AND CONSERVATION IMPLICATIONS

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Tesis presentada para optar al grado de Magíster Scientiae en Medicina de la Conservación con énfasis en Salud Ecosistémica. Cumple con los requisitos establecidos por el Sistema de Estudios de Posgrado de la Universidad Nacional, Heredia, Costa Rica.

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## I. Resumen / Abstract

Costa Rica alberga dos especies de perezosos: *Bradypus variegatus* (BV) y *Choloepus hoffmanni* (CH), ambas cada vez más afectadas por presiones antropogénicas. Este estudio analizó 2,247 ingresos registrados en 10 Centros de Rescate de Vida Silvestre (CRVS) entre 2012 y 2022, integrando los datos de admisión con información georreferenciada para identificar los principales factores de ingreso, diferencias entre especies, zonas críticas y desafíos de conservación.

Los ingresos mostraron un incremento sostenido, con una tasa media de crecimiento anual del 8.7% entre 2018 y 2022, salvo una disminución del 5.6% en 2020 atribuida a la pandemia de COVID-19. Los picos de ingreso se concentraron en los meses de diciembre–enero y julio–agosto, coincidiendo con los ciclos reproductivos y turísticos. CH fue admitido casi el doble de veces que BV. La tasa de supervivencia fue idéntica (43.9%), pero BV presentó una mayor tasa de liberación exitosa (40.8% frente a 30.3%), aunque con una menor permanencia en cautiverio (28 frente a 42 días) y una mayor mortalidad en ejemplares huérfanos (71.7% frente a 57.3%).

Más del 60% de los rescates se realizaron en la región del Caribe Sur, con focos adicionales en las Zonas Central y Pacífica. Zonas como Guápiles y el Caribe Norte, caracterizadas por alta densidad poblacional pero limitada cobertura de rescate, fueron identificadas como prioritarias.

Los hallazgos confirman la mayor vulnerabilidad de BV en condiciones de cautiverio y señalan las electrocuciones, ataques de perros y atropellos vehiculares como las amenazas antropogénicas más apremiantes. Se destaca la necesidad de implementar estrategias preventivas coordinadas y fortalecer la colaboración entre los CRVS, universidades e instituciones nacionales para una conservación basada en evidencia. Este trabajo subraya la importancia de incorporar los datos de rescate en las políticas nacionales de conservación para proteger la biodiversidad de Costa Rica.

## II. Agradecimientos

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### III. Índice

I.	Resumen / Abstract .....	4
II.	Agradecimientos .....	5
III.	Índice .....	6
IV.	Lista de cuadros .....	7
V.	Descriptores .....	8
VI.	Introducción General .....	8
VII.	Conclusiones generales .....	10
VIII.	Recomendaciones generales .....	11
IX.	Referencias generales .....	12
X.	Artículo I .....	16
	A. Introducción	
	B. Materiales y Métodos	
	C. Resultados y Discusión	
	D. Conclusiones	

## IV. Lista de Cuadros

### Sección general

**Fig. A.** Cladograma de las relaciones filogenéticas dentro del orden Pilosa. La flecha azul señala los géneros extantes (Toledo, 2017).

**Fig. B.** Mapa de Costa Rica que ilustra las Áreas Silvestres Protegidas y los 43 Corredores Biológicos oficialmente reconocidos.

### Artículo: Figuras (*Figuras y artículo escritos en lengua inglesa*)

**Fig. 1.** Survival and release outcomes for *Choloepus hoffmanni* (CH) and *Bradypus variegatus* (BV). (**a, left**) Bar graph showing total numbers; (**b, right**) Pie chart showing percentages.

**Fig. 2.** Temporal trends in sloth admissions. (**a, top**) Annual admissions showing seasonal peaks by species; (**b, bottom**) Yearly trends of admissions (2012–2022), including declines in 2018 and 2020.

**Fig. 3.** Map of Costa Rica with distribution of sloth rescues (CH and BV), Rescue centers and Protected wilderness areas.

**Fig. 4.** Map of Costa Rica with distribution of sloth observation from citizen science GBIF portal (SINAC/INBio).

**Fig. 5.** Rescue altitude ranges showing by species (BV and CH)

**Fig. 6.** Distribution of admissions among rescue centers

**Fig. 7.** Map of Costa Rica with density hotspot areas of sloth admissions, species distribution and rescue center locations.

**Fig. (8a, top)** Sex ratios of admitted sloths. (**8b, bottom**) Age distribution of admitted sloths (babies, juveniles, adults).

**Fig. 9.** Length of stay in rehabilitation by species, according to cause of admission.

**Fig. 10.** Causes of admission in sloths. **(a, top)** Admission causes by species and their outcomes; **(b, bottom)** Leading admission causes with species differences.

**Fig. 11.** Temporal trends for each cause of admission. **(a, top)** Monthly admissions by cause; **(b, bottom)** Annual trends in admission causes since 2013.

**Fig. 12.** Seasonal patterns of orphan admissions. **(a, top)** Seasonal patterns by species; **(b, bottom)** Regional differences in orphan seasonality, comparing Caribbean rescue centers with the rest of the country.

**Fig. 13.** Geographic distribution of orphan cases.

**Fig. 14.** Season patterns of electrocution admissions. **(a, top)** Comparison of WRC electrocution records by species with ICE data. **(b, bottom)** Annual trend of electrocution admissions comparing WRCs and ICE data.

**Fig. 15.** Geographic distribution of electrocution cases, showing WRC rescue records alongside ICE data and infrastructure.

**Fig. 16.** Seasonal patterns of admissions of sloths bitten by dogs.

**Fig. 17.** Geographic distribution of dog attack cases.

**Fig. 18.** Geographic distribution of hit-by-car cases.

**Fig. 19.** Geographic distribution of injured, sick, or weak sloth admissions.

**Fig. 20.** Seasonal distribution of sloth falls by region.

**Fig. 21.** Geographical distribution of sloth falls.

**Fig. 22.** Geographical distributions of translocations of sloths.

**Table 1.** Mean and median distances of sloth rescues according to wildlife rescue centers.

## V. Descriptores

### *Especies objetivo del estudio*

Este estudio se fundamenta en datos de dos especies emblemáticas: el perezoso de tres dedos de garganta café (*Bradypus variegatus*) y el perezoso de dos dedos de Hoffmann (*Choloepus hoffmanni*). Costa Rica alberga una biodiversidad excepcional. Según la Unión Internacional para la Conservación de la Naturaleza (UICN), el número de especies de fauna amenazadas en Costa Rica ha aumentado en los últimos años en paralelo al incremento del número total de especies evaluadas. De acuerdo con las estadísticas oficiales de la IUCN Red List, el número de especies clasificadas como Vulnerables, En Peligro o En Peligro Crítico pasó de 185 en 2014 a 212 en 2019, mientras que el total de especies evaluadas aumentó de 2.525 a 3.756. Aunque este incremento absoluto es relevante, la proporción de especies amenazadas dentro del conjunto evaluado se ha mantenido relativamente estable durante este periodo (UICN, 2014; UICN, 2019).

### *Xenarthra*

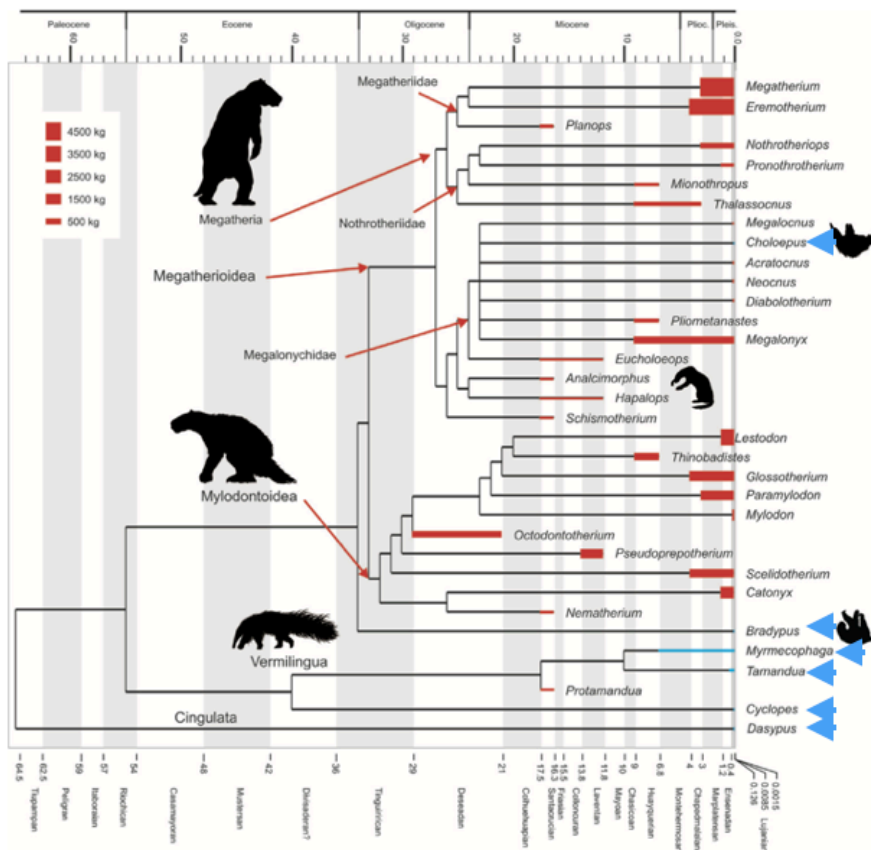
Los perezosos pertenecen al superorden Xenarthra, un linaje monofilético de mamíferos placentarios endémico de América. Este grupo comprende dos órdenes: *Pilosa*, que incluye a los osos hormigueros y los perezosos, y *Cingulata*, que agrupa a los armadillos (Superina & Loughry, 2020). Los xenartros constituyen una de las cuatro principales ramas evolutivas de los mamíferos placentarios y poseen una extensa historia evolutiva.

Actualmente, se reconocen 30 especies vivientes distribuidas en 13 géneros, aunque el registro fósil evidencia una diversidad mucho mayor, con 218 géneros identificados. Hasta hace apenas 10,000 años, los xenartros aún mostraban una alta diversificación, pero la mayoría de los géneros se extinguieron, probablemente como resultado de la presión antropogénica combinada con cambios climáticos (Delsuc et al., 2001).

A pesar de sus diferencias morfológicas, los xenartros comparten varias sinapomorfias, como articulaciones intervertebrales adicionales, dientes sin esmalte ni raíces que crecen de forma continua en perezosos y armadillos, y la ausencia total de dentición en los osos hormigueros. También presentan particularidades fisiológicas, como tasas metabólicas basales bajas y temperaturas corporales variables, lo que los convierte en los mamíferos placentarios con menor capacidad de termorregulación (Superina & Loughry, 2020). En los perezosos, esta condición se relaciona con una masa muscular reducida y una locomoción suspendida, lo que disminuye significativamente sus requerimientos energéticos (McNab, 1985).

## Clasificación

- **Order Pilosa**
  - Suborder Vermilingua – osos hormigueros
    - Familia Cyclopedidae (1 especie en Costa Rica, 3 mundialmente)
    - Familia Myrmecophagidae (1 especie en Costa Rica, 3 mundialmente)
  - Suborder Folivora – perezosos
    - Familia Bradypodidae (*Bradypus variegatus*, 1 especie en Costa Rica, 4 mundialmente)
    - Familia Megalonychidae (*Choloepus hoffmanni*, 1 especie en Costa Rica, 2 mundialmente)
- **Order Cingulata – armadillos**
  - Familia Dasypodidae (2 especies en Costa Rica, 20 mundialmente)



**Fig A.** Cladograma de las relaciones filogenéticas dentro del orden Pilosa. La flecha azul señala los géneros extantes (Toledo, 2017).

## ***Ecología de los perezosos en Costa Rica***

Si bien estudios clásicos caracterizaron a *C. hoffmanni* como predominantemente nocturno y a *B. variegatus* como más diurno o con patrones de actividad variables (Sunquist & Montgomery, 1973; Chiarello, 2008), investigaciones recientes basadas en registros continuos sugieren que ambas especies presentan actividad catemeral, es decir, actividad distribuida tanto durante el día como la noche, con alta variabilidad individual (Castro-Sa et al., 2021; Cliffe et al., 2023).

En el bosque húmedo tropical de tierras bajas de Costa Rica, Cliffe et al. (2023) observaron que individuos de ambas especies exhiben patrones de actividad flexibles a lo largo del ciclo de 24 h, con picos de actividad que varían según las condiciones ambientales. No obstante, persisten diferencias en cuanto a movilidad y comportamiento de desplazamiento: *Bradypus* tiende a permanecer por períodos prolongados en el mismo árbol o área reducida, mientras que *Choloepus* se desplaza con mayor frecuencia entre árboles y recorría distancias diarias más extensas (Sunquist & Montgomery, 1973; Chiarello, 2008; Peery & Pauli (2014) .

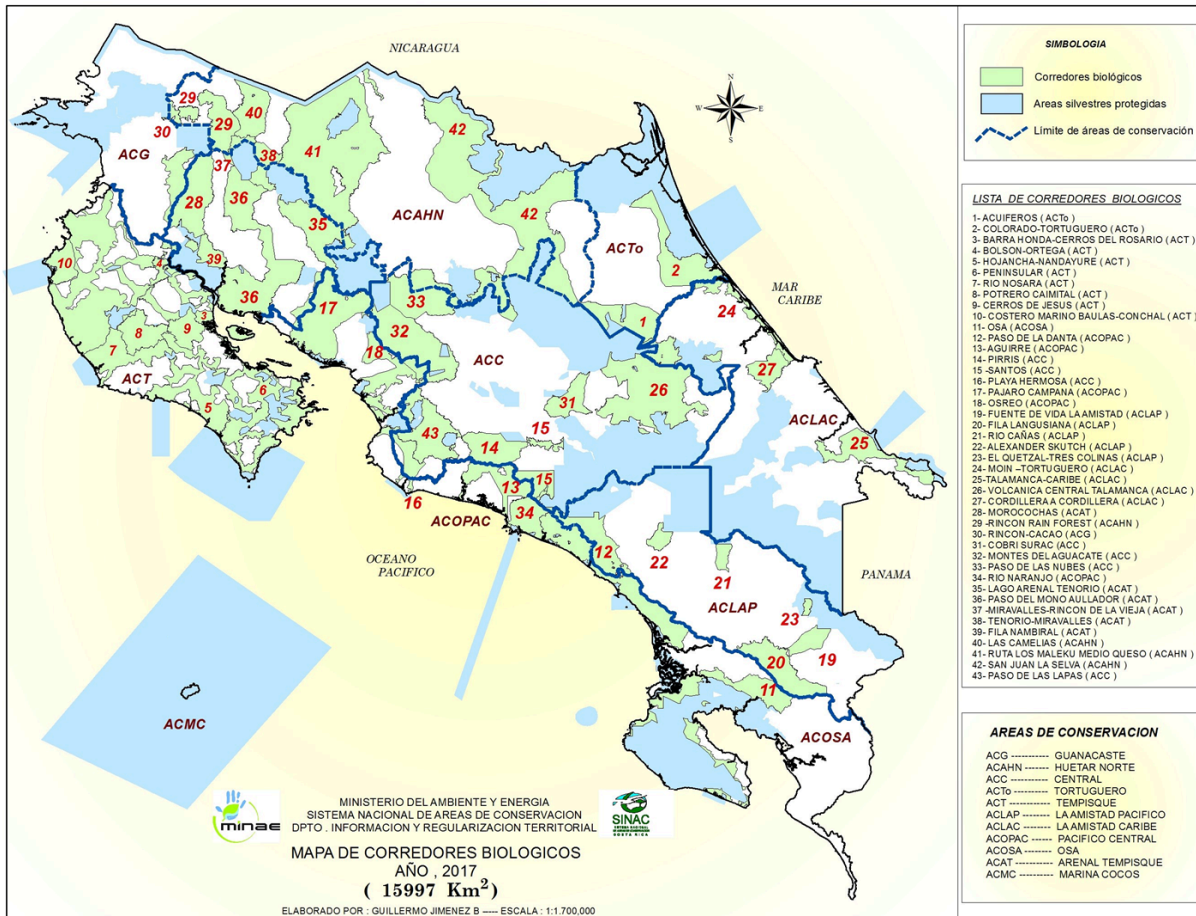
El tamaño del área de acción es relativamente reducido, oscilando entre 0.04 y 0.6 hectáreas en individuos juveniles, y entre 0.04 y 25 hectáreas en hembras adultas (Vaughan et al., 2007). Su biología y comportamiento los hacen particularmente susceptibles a la fragmentación del hábitat, colisiones vehiculares, electrocuciones en tendidos eléctricos y ataques por parte de perros domésticos (Plese & Chiarello, 2015).

## **Sistema Nacional de Áreas Protegidas de Costa Rica**

El Sistema Nacional de Áreas de Conservación (SINAC) administra más de 160 Áreas Silvestres Protegidas (ASP), que incluyen parques nacionales, reservas biológicas, refugios de vida silvestre y zonas protegidas. En conjunto, estas áreas abarcan aproximadamente el 25% del territorio nacional (SINAC, 2021). Esta extensa red ha sido clave para revertir las tendencias de deforestación y consolidar la protección de la biodiversidad, aunque persisten desafíos derivados de la expansión urbana, el desarrollo agrícola y los impactos asociados a la infraestructura vial y eléctrica (Fallas & Quesada, 2017).

Como complemento a la red de ASP, Costa Rica ha promovido el establecimiento de Corredores Biológicos, unidades de gestión voluntaria diseñadas para conectar áreas protegidas y mantener los procesos ecológicos en paisajes fragmentados. A diferencia de las ASP, los corredores integran la conservación con el uso sostenible del suelo por parte de los seres humanos, mediante la participación activa de comunidades locales, organizaciones no gubernamentales e instituciones públicas (SINAC, 2017).

El mapa que se presenta a continuación ilustra este sistema dual (Fig. B). Las áreas en azul claro representan las Áreas Silvestres Protegidas, mientras que las zonas en verde indican los 43 Corredores Biológicos oficialmente reconocidos, y las líneas punteadas marcan los límites de las 11 áreas de conservación. En conjunto, reflejan el enfoque costarricense de combinar la protección estricta con la conectividad del paisaje.



**Fig B.** Mapa de Costa Rica que ilustra las Áreas Silvestres Protegidas y los 43 Corredores Biológicos oficialmente reconocidos. Fuente: SINAC, 2025.

Si bien estas áreas protegidas desempeñan un papel importante en la protección de las poblaciones de perezosos, la mayoría de los rescates ocurren fuera de sus límites, en paisajes agrícolas, periurbanos o turísticos donde el conflicto entre humanos y fauna silvestre es más intenso. Esto resalta la importancia de estrategias de conservación que trasciendan los parques nacionales e integren la planificación del uso del suelo, iniciativas de conectividad y la participación comunitaria.

## **Historia y función de los centros de rescate de vida silvestre en Costa Rica**

Los centros de rescate de vida silvestre (CRVS) comenzaron a expandirse en el país durante la década de 1980, con un enfoque inicial en la rehabilitación de animales incautados del comercio ilegal de fauna silvestre o lesionados por conflictos directos con personas. En la actualidad, existen más de 20 instituciones activas, en su mayoría privadas o sin fines de lucro, que operan bajo la supervisión del Ministerio de Ambiente y Energía (MINAE) y del Sistema de Áreas de Conservación (SINAC) (Soto, 2018).

Estos centros cumplen una doble función. Por un lado, brindan atención veterinaria, rehabilitación y, cuando es posible, liberación de animales silvestres. Por otro, generan conjuntos de datos valiosos que permiten caracterizar amenazas y tendencias a nivel regional y nacional. Aunque en muchos casos los registros son fragmentados o carecen de estandarización, al ser integrados ofrecen una perspectiva única sobre la interacción entre la fauna silvestre y las actividades humanas (Taylor-Brown et al., 2019; Molina-López & Darwich, 2011).

El creciente número de perezosos admitidos en estos centros, especialmente en zonas turísticas y periurbanas, refleja la exposición cada vez mayor de la especie a amenazas antropogénicas. Por ello, la colaboración entre los centros de rescate, la academia y el gobierno resulta esencial para transformar los datos de rescate en insumos prácticos para la planificación de la conservación y la formulación de políticas públicas.

## **VI. Introducción**

Costa Rica es reconocida internacionalmente como uno de los principales puntos calientes de biodiversidad del planeta, al albergar cerca del 5% de las especies globales dentro de su territorio de 51,100 km<sup>2</sup> (Myers et al., 2000; Langhans et al., 2022). El país ha asumido históricamente un liderazgo en conservación, con más del 25% de su superficie terrestre bajo alguna forma de protección (CBD Country Dossier: Costa Rica, 2021). No obstante, a pesar de esta sólida red de protección, la biodiversidad costarricense continúa enfrentando presiones derivadas de la fragmentación del hábitat, la expansión de infraestructura y la urbanización (Hecht et al., 2012).

El monitoreo del estado de salud y las poblaciones de fauna silvestre en su hábitat natural suele estar limitado por desafíos logísticos y ecológicos, especialmente en especies como los perezosos, cuyo comportamiento críptico y hábitos arborícolas dificultan las evaluaciones directas. Los CRVS ofrecen una fuente de información prometedora pero subutilizada. Estos centros reciben animales silvestres afectados por amenazas naturales y antropogénicas como caídas, colisiones vehiculares, electrocuciones y ataques de perros, y registran las circunstancias de su ingreso, tratamiento y desenlace (Molina-López & Darwich, 2011; Taylor-Brown et al., 2019).

Los perezosos de Costa Rica (*Bradypus variegatus* y *Choloepus hoffmanni*) poseen una relevancia tanto biológica como cultural. Su historia de vida lenta y dependencia del dosel forestal los hace particularmente vulnerables al cambio ambiental, mientras que su popularidad los convierte en un grupo emblemático cuya protección puede beneficiar ecosistemas más amplios. En agosto de 2021, Costa Rica declaró legalmente a ambas especies como símbolos nacionales de la fauna silvestre (Asamblea Legislativa de Costa Rica, 2021), destacando su importancia ecológica y social.

A pesar de este reconocimiento, la mayoría de los estudios previos que utilizan datos de rescate han sido de alcance limitado, centrados en centros individuales, regiones específicas o tipos de amenaza particulares como atropellos (Villalobos-Hoffman et al., 2022). El valor de integrar datos entre múltiples centros radica en la posibilidad de revelar patrones nacionales y regionales que los estudios aislados no pueden detectar.

Esta tesis aborda dicha brecha mediante la compilación y análisis de 2,247 registros de ingreso de perezosos en 10 CRVS entre 2012 y 2022. Se examinan las causas de ingreso, los patrones temporales y espaciales, los desenlaces específicos por especie y la logística de rescate, proporcionando el primer panorama nacional coordinado sobre el rescate de perezosos en el país. De manera más amplia, los hallazgos destacan el potencial de las redes de CRVS para vincular datos de campo con la planificación de la conservación, el desarrollo de políticas públicas y estrategias de mitigación. El conjunto de datos generado en esta tesis también sirve como base para el artículo científico titulado “Admissions of Sloths (*Bradypus variegatus* and *Choloepus hoffmanni*) in Costa Rican Rescue Centers (2012–2022): Spatio-Temporal Patterns, Threats, Survival Outcomes, and Conservation Implications”.

En última instancia, este trabajo enfatiza la necesidad de colaboración entre los CRVS, las universidades y las agencias gubernamentales para convertir registros fragmentados en estrategias coordinadas basadas en evidencia. Cuando los datos de rescate se integran de manera efectiva, se convierten en una herramienta poderosa no solo para mejorar el bienestar de los perezosos, sino también para fortalecer la conservación de la biodiversidad costarricense en su conjunto.

## VII. Conclusiones Generales

Esta tesis presenta el primer panorama nacional coordinado sobre el rescate de perezosos en Costa Rica y demuestra que los CRVS constituyen una herramienta poderosa para comprender cómo las actividades humanas influyen en los desenlaces de la fauna silvestre. Las admisiones aumentaron durante la última década, con una leve disminución en 2020 debido a las restricciones de movilidad por la pandemia de COVID-19, mostrando picos estacionales consistentes que se alinean con los ciclos turísticos y reproductivos. Estos patrones temporales pueden ayudar a anticipar y orientar medidas de mitigación y acciones de sensibilización comunitaria durante los períodos de mayor ingreso.

Los resultados específicos por especie revelan implicaciones claras para la gestión. *C. hoffmanni* ingresó a los centros de atención casi el doble de veces que *B. variegatus*, aunque la tasa de supervivencia general en cuidado fue similar para ambas especies. *Bradypus* presentó mayor éxito de liberación, pero también mayor fragilidad en cautiverio, con menor tiempo hasta la muerte y una tasa de mortalidad marcadamente más alta en individuos huérfanos. Estas y otras diferencias identificadas en el estudio señalan la necesidad de protocolos de rehabilitación diferenciados por especie. El cuidado de huérfanos emerge como un desafío crítico para ambas especies y una mayor colaboración entre los CRVS para compartir experiencias y desarrollar protocolos estandarizados de crianza, rehabilitación y liberación que podría mejorar sustancialmente los desenlaces de supervivencia y aumentar el éxito general a nivel nacional.

Los análisis espaciales identifican dónde la prevención tendría mayor impacto. Más del 60% de los rescates ocurrieron en el Caribe Sur, con concentraciones adicionales en la región central y el Pacífico Central. Los parques nacionales generaron menos rescates, mientras que los paisajes dominados por humanos produjeron más, lo que indica que las medidas de mitigación deben integrarse en los espacios donde conviven y se movilizan tanto los perezosos como las personas. La cobertura de rescate es desigual. Zonas de la provincia de Limón como Guápiles y el Caribe Norte muestran alta presencia de perezosos y amenazas frecuentes, pero cuentan con capacidad limitada de rescate. Puntarenas y algunas zonas del Pacífico Sur también están subatendidas. Establecer o fortalecer puestos satélite de rescate, mejorar la coordinación con SINAC y otras instituciones oficiales y financiar personal capacitado como primeros respondedores en estas áreas, contribuiría a reducir el tiempo de atención y mejorar los resultados.

Los patrones de altitud y distribución sugieren estrategias de hábitat complementarias. *B. variegatus* se encontró mayormente confinado a tierras bajas y fue rescatado casi exclusivamente por debajo de los 100 m.s.n.m., mientras que *C. hoffmanni* se distribuyó en un rango altitudinal más amplio, hasta los 2,400 m.s.n.m. Estas diferencias deben guiar la ubicación de puentes de dosel, el diseño de corredores vegetales y la micro planificación de los sitios de liberación.

Entre las principales amenazas identificadas, la electrocución destaca claramente como la causa principal de ingreso y una fuente significativa de mortalidad, especialmente para *B. variegatus*.

La discrepancia entre los datos de los CRVS y los reportes del Instituto Costarricense de Electricidad (ICE) evidencia una subestimación de su impacto real y subraya la necesidad de medidas preventivas en origen. Los ataques de perros también representan una presión considerable, particularmente en la región caribeña, donde existe una alta superposición entre los hábitats de los perezosos y los asentamientos humanos. Las colisiones vehiculares, aunque menos frecuentes, se asociaron consistentemente con las tasas de mortalidad más altas y se concentraron en corredores de transporte específicos, lo que resalta el papel de la planificación de infraestructura en la conservación. Las causas naturales como las caídas también fueron comunes, a menudo vinculadas a la fragmentación del dosel y la deforestación, recordándonos que la integridad del paisaje es fundamental para la supervivencia de los perezosos.

Más allá de las amenazas, el estudio también revela cómo la estructura de la capacidad de rescate influye en los resultados. Los centros costeros tienden a atender rescates locales en distancias más cortas, mientras que los centros del interior del país dependen en gran medida de instituciones externas para transportar animales desde áreas de captación mucho más amplias. Esta desarticulación, junto con la distribución geográfica de las admisiones y los datos conocidos sobre observaciones y amenazas a los perezosos, sugiere que expandir o reforzar la capacidad de rescate en zonas subatendidas como Guápiles, Puntarenas y el Pacífico Sur, es esencial para reducir demoras y mejorar la atención.

En conjunto, estos resultados muestran que la conservación de los perezosos en Costa Rica no puede depender únicamente de la rehabilitación. Las medidas preventivas deben priorizarse en las áreas de mayor riesgo, en particular las redes eléctricas, las interfaces entre perros y fauna silvestre, y los puntos críticos de atropello identificados. Al mismo tiempo, fortalecer la red de CRVS no solo mejorará los resultados inmediatos en bienestar animal, sino que también reforzará la respuesta nacional ante las amenazas a la biodiversidad en general. Esta tesis demuestra el valor de integrar los datos de rescate en la planificación de la conservación y hace un llamado a una colaboración más estrecha entre los CRVS, las universidades y las instituciones gubernamentales para diseñar estrategias de mitigación basadas en evidencia que protejan a los perezosos y otras especies de fauna silvestre en todo el país.

## VIII. Recomendaciones Generales

Los resultados de esta tesis ofrecen evidencia clara de que la conservación de los perezosos en Costa Rica requiere acciones coordinadas que trasciendan la rehabilitación. A partir del análisis de los ingresos registrados en múltiples CRVS, se pueden plantear varias recomendaciones generales:

1. Es esencial la estandarización en la recolección y gestión de datos entre los CRVS. El establecimiento de directrices comunes para el registro de causas de ingreso, desenlaces clínicos, información georreferenciada y resultados de liberación permitiría realizar análisis más sólidos a nivel nacional. Este esfuerzo debe ser coordinado por el SINAC en colaboración con universidades, organizaciones no gubernamentales de conservación y los propios CRVS, garantizando que los datos de rescate se conviertan en una fuente confiable de información para la toma de decisiones.
2. Se requiere fortalecer la comunicación y cooperación entre instituciones. Los CRVS, las agencias gubernamentales, el ICE, universidades, grupos de investigación y conservación, municipalidades y organizaciones comunitarias deben trabajar conjuntamente para compartir información y alinear acciones de conservación. Esto incluye integrar los datos de rescate con conjuntos de datos externos (por ejemplo, reportes de atropellos, incidentes con líneas eléctricas, plataformas de ciencia ciudadana), creando un sistema integral de monitoreo de amenazas para los perezosos y otras especies silvestres, así como coordinar planes de acción en una dirección común.
3. Los resultados de esta tesis deben aplicarse directamente para orientar las prioridades de conservación y las estrategias de mitigación. Los puntos críticos de electrocución, las regiones con frecuentes ataques de perros y los corredores viales de alto riesgo requieren intervenciones específicas como modificaciones en infraestructura, programas de educación comunitaria e iniciativas de conectividad de hábitat. Ampliar la cobertura de rescate en regiones subrepresentadas como Guápiles, Puntarenas y el Pacífico Sur también contribuiría a reducir las discrepancias entre las amenazas existentes y las respuestas disponibles.
4. Finalmente, los perezosos pueden desempeñar el papel de especie sombrilla para la planificación de una conservación de la biodiversidad más amplia en el país. Las acciones que reduzcan la electrocución, la depredación por perros y los atropellos también beneficiarán a otras especies arbóreas y terrestres que comparten los mismos paisajes. Por lo tanto, se recomienda que los datos de rescate y los hallazgos de este estudio se incorporen en las políticas nacionales de conservación y en los procesos de planificación del uso del suelo, reforzando el papel de Costa Rica como líder global en la protección de la biodiversidad.

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**X. Admissions of Sloths (*Bradypus variegatus* and *Choloepus hoffmanni*) in Costa Rican Rescue Centers (2012–2022): Spatio-Temporal Patterns, Threats, Survival Outcomes, and Conservation Implications**

Sustentante

Fernando Alegre Alonso

Manuscrito preparado con el formato para la revista:

*Plos One*

# Admissions of Sloths (*Bradypus variegatus* and *Choloepus hoffmanni*) in Costa Rican Rescue Centers (2012–2022): Spatio-Temporal Patterns, Threats, Survival Outcomes, and Conservation Implications

## Abstract

Costa Rica is home to two sloth species, *Bradypus variegatus* (BV) and *Choloepus hoffmanni* (CH), both increasingly affected by anthropogenic pressures. This study analyzed 2,247 admissions from 10 wildlife rescue centers (WRCs) between 2012 and 2022, integrating admission records with georeferenced data to identify main drivers, species differences, hotspots, and conservation challenges.

Admissions rose steadily, with an average annual growth of 8.7% from 2018 to 2022, except for a 5.6% decline in 2020 linked to COVID-19. Admissions peaks occurred in December–January and July–August, coinciding with reproductive and tourism cycles. CH were admitted nearly twice as often as BV. Survival was identical (43.9%), but BV achieved higher release success (40.8% vs. 30.3%) while dying sooner in captivity (28 vs. 42 days) and showing higher orphan mortality (71.7% vs. 57.3%). Over 60% of rescues occurred in the South Caribbean, with additional hotspots in the central and Pacific regions. Regions such as Guápiles and the northern Atlantic, with dense populations but scarce rescue coverage, were identified as priorities.

Findings confirm BV's greater fragility in captivity and highlight electrocutions, dogs, and vehicles as the most urgent threats. Coordinated prevention and stronger collaboration between WRCs, universities, and national institutions are essential for evidence-based conservation. This work reinforces the importance of integrating rescue data into national conservation policies to safeguard Costa Rica's biodiversity.

## Introduction

Costa Rica, a global biodiversity hotspot, harbors nearly 5% of the world's species within its relatively small territory of 51,100 km<sup>2</sup>. The country has long been recognized for pioneering conservation policies, with more than a quarter of its land under protection. Despite these successes, Costa Rica's biodiversity continues to face mounting pressures from habitat loss, urban expansion, infrastructure development, and other human activities (Stonich, 1999; Criado-Hernández, 2013).

Among its most emblematic species are sloths, which have become a national wildlife symbol since 2021 (Asamblea Legislativa de Costa Rica, 2021) and a favorite attraction for residents and visitors alike. Two species inhabit Costa Rica: the brown-throated three-toed sloth (*Bradypus variegatus*, BV) and Hoffmann's two-toed sloth (*Choloepus hoffmanni*, CH). Both display

flexible activity patterns that help them adapt to environmental pressures and avoid predators (Gilmore et al., 2001; Oliveira Bezerra et al., 2020; Cliffe et al., 2023), and both rely on specialized habitats and ecological relationships that make them vulnerable to disturbance (Vaughan et al., 2007).

Despite their popularity and resilience, sloths are frequently affected by anthropogenic threats, including electrocution, dog attacks, and vehicle collisions, in addition to natural causes such as falls from fragmented canopies. Understanding how these threats affect populations is crucial for conservation, yet obtaining robust data on wild sloth populations remains challenging.

Wildlife Rescue Centers (WRCs) provide an essential but underused source of information. These centers admit thousands of animals each year, including large numbers of sloths, and record the causes of admission, outcomes, and geographic origins of cases. As mostly private institutions, they work closely with official bodies such as the Ministry of Environment, police, and firefighters, as well as local citizens. Beyond their rehabilitation role, WRCs generate valuable datasets that reflect both ecosystem health and the pressures exerted on wildlife (Molina-López & Darwich, 2011; Sleeman, 2008; Taylor-Brown et al., 2019; Timm & Kime, 2020). However, most studies using WRC data remain limited to single centers, regions, or specific issues such as roadkill, infectious diseases, or dog attacks (Monge-Nájera, 2018), without an integrated analysis of data.

To address this gap, the present study provides the first nationwide, multi-center analysis of sloth admissions in Costa Rica and Latin America, compiling data from 10 WRCs between 2012 and 2022. By integrating admission records with georeferenced information, the study identifies key causes of rescue, species-specific differences, and spatial patterns of threat. As a charismatic flagship species, sloths offer a valuable case study for understanding how human activities shape wildlife survival. Insights from this work not only strengthen evidence-based strategies for sloth conservation but also provide a model that can be applied to other species and broader wildlife management efforts across tropical countries like Costa Rica.

## **Materials and Methods**

### **Study Area, Rescue Centers, and Climate Context**

This study was conducted using data from ten wildlife rescue centers located across three provinces of Costa Rica, which collectively receive animals originating from all regions of the country. According to the Ministry of Environment and Energy (SINAC-MINAE), these facilities have the highest sloth caseloads in the country. To preserve confidentiality, the association between results and specific centers is not disclosed; instead, the centers are anonymized and coded from A to J in all figures.

These rescue centers cover a wide range of ecosystems from humid lowland rainforest to premontane forest and dry tropical forest. Costa Rica has a tropical climate strongly influenced by topography and the Pacific and Caribbean coasts. On the Pacific slope and Central Valley, rainfall follows a marked seasonality with a dry period from December to April and a rainy season from May to November, often interrupted by a short midsummer drought in July–August (Magaña et al., 1999). In contrast, the Caribbean coast receives precipitation year-round, with peaks in June–August and December–February, and relative minima in March–April and September–October (Orozco-Montoya & Penalba, 2022). Annual rainfall exceeds 5,000 mm on the Caribbean slopes, while Pacific and inland regions typically receive 1,500–2,500 mm (Solano & Villalobos, 2001). These climatic distinctions are ecologically relevant for interpreting sloth admissions, as rainfall seasonality, habitat moisture, and temperature influence both sloth ecology and human–wildlife interactions.

### **Data Compilation and Integration**

A total of 2,247 records for the two sloth species were analyzed over 11 years, with some rescue centers contributing more recent data. Only animals that arrived alive were included. Data collection methods varied among centers and included structured databases, Excel spreadsheets, and paper records. For each animal, the following variables were requested: entry date, exit or death date, scientific name, outcome (release [R], death [D], sanctuary [S], still under rehabilitation [C], or transferred [T]), reason for admission, and location. Records lacking all three key data points (location, reason for admission, or entry date) were excluded from the analysis. Although some centers also provided additional information about the rescue circumstances, these data were excluded due to inconsistencies among centers. All validated records were subsequently integrated and consolidated into a spreadsheet (Numbers v.13.2, Apple Inc., Cupertino, USA).

None of the entries included GPS coordinates of the incidents. Coordinates were therefore estimated from the location descriptions provided, using Google Maps (Google LLC, Mountain View, CA, USA). In most cases, these descriptions were sufficiently detailed to assign precise coordinates, while in others only the general region could be determined, requiring approximations. This limitation reduces the geographical resolution and the strength of local-scale conclusions from the spatial analysis. Still, it does not compromise the broader patterns of rescue distribution across the study area.

### **Categorization of Admission Causes**

Admission causes were recorded by veterinarians or designated staff based on the initial examination and rescue circumstances. These were standardized into 14 categories: orphaned;

injured, weak, or sick; dog attack; fall from a tree; electrocution; translocation; hit by a car; confiscated as a pet; intraspecific aggression; return after release; human attack; born in a rescue center; transferred from another rescue center; and other.

Data from all centers were aggregated, and each case was assigned to one of these categories. When multiple causes were involved, classification was based on the predominant cause (e.g., a baby sloth, both orphaned and struck by a vehicle, was categorized as “hit by a car”). For some records without an explicitly stated cause, classification was inferred from available case details and physical examination findings, following approaches previously applied in wildlife rescue studies.

## **Data Analysis**

Data were processed using Numbers (Apple Inc.) and ArcGIS Pro (Esri). Spatial analyses were conducted in ArcGIS Pro to explore geographic patterns of sloth admissions. This data generated heat distribution maps, allowing visualization of spatial concentration and intensity of cases across the study area. Admission locations were georeferenced and overlaid with environmental and anthropogenic layers, including road networks, protected area boundaries or altitude, to assess spatial associations.

In addition, spatiotemporal analyses were applied to evaluate temporal trends and seasonal variation in admissions, identifying clusters of cases across both space and time. These approaches facilitated the detection of geographic hotspots and temporal patterns, providing insights into factors potentially influencing sloth admissions and their spatial distribution.

## **Results and Discussion**

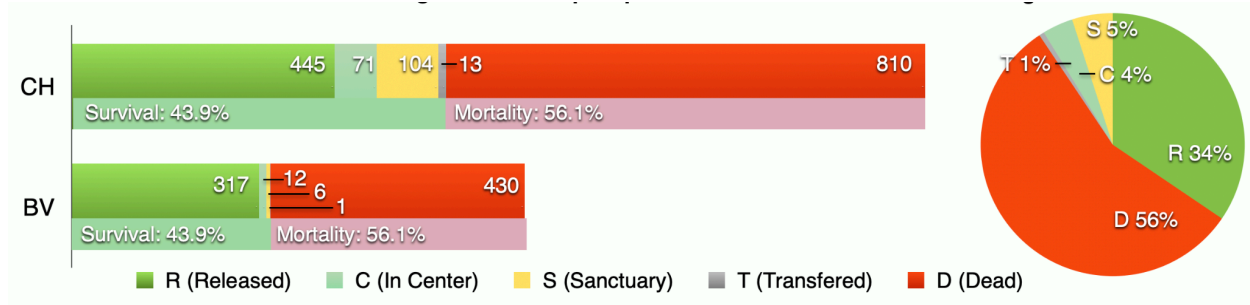
### **General data overview of species and outcome**

Sloth admission records from 10 wildlife rescue centers in Costa Rica were analyzed for the period 2012–2022, encompassing a total of 2,247 individuals. Of these, 1,955 (87.0%) included sufficient location detail to extract geographic coordinates, 2,209 (98.3%) contained outcome information (release [R], death [D], transfer [T], under rehabilitation [C], or permanent sanctuary [S]), and 2,180 (97.0%) documented a cause of admission.

The majority of admissions corresponded to CH, with 1,470 individuals (65.4%), while BV accounted for 777 individuals (34.6%). The study shows that two-toed sloths are nearly twice as often admitted to rescue centers in Costa Rica as three-toed sloths during the study period.

Of the 2,209 individuals with documented outcomes, 1,240 (56.1%) died and 969 (43.9%) survived. Among the survivors, 762 were released, representing 34.5% of all admissions and

78.6% of those who survived. Overall survival rates were nearly identical between CH (43.9%) and BV (43.9%). However, release success differed between species: BV showed a higher release rate (40.8%) compared to CH (30.3%) (Fig. 1a, 1b).

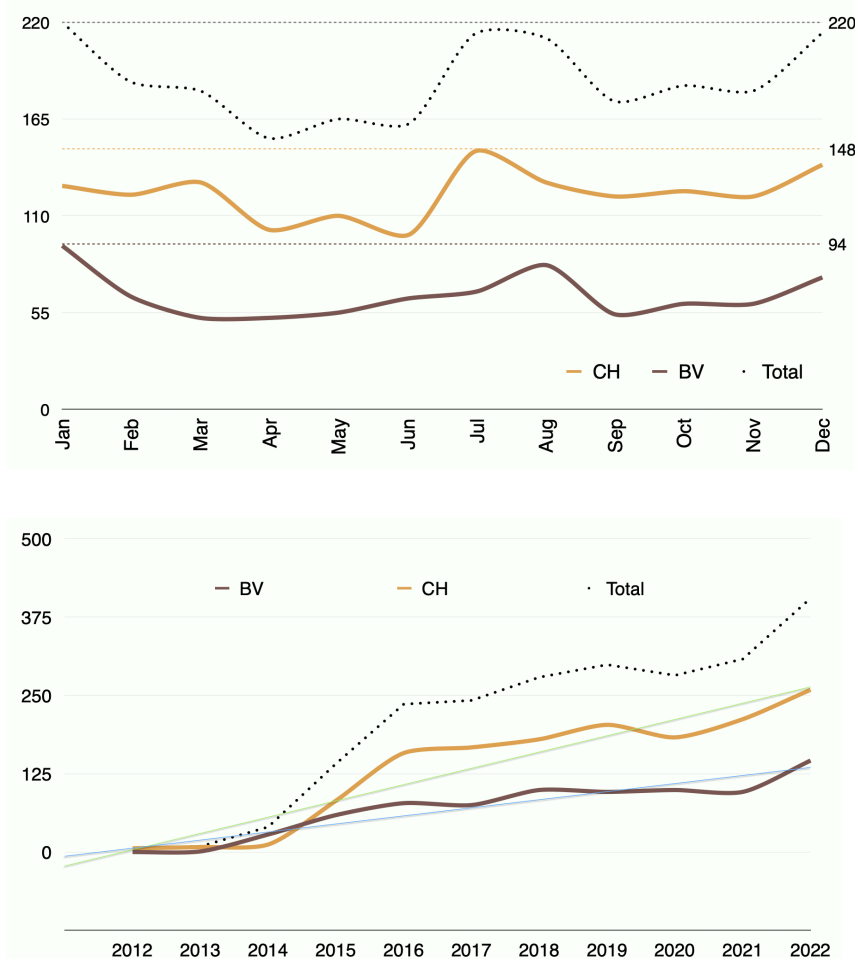


**Fig. 1.** Survival and release outcomes for *Choloepus hoffmanni* (CH) and *Bradypus variegatus* (BV). (a, left) Bar graph showing total numbers; (b, right) Pie chart showing percentages.

At the time of the study, 207 animals (9.4%) remained in captivity. This group was disproportionately composed of CH (n = 188) compared to BV (n = 19). Among the BV, only six were permanent sanctuary residents, while the remainder were still under rehabilitation. This imbalance highlights the greater difficulty of maintaining BV in captivity for extended periods. Possible explanations include a comparatively weaker immune system in BV, which may increase susceptibility to captivity-associated diseases (Sunquist, 1973), and a more specialized diet, as BV primarily consume leaves from a limited number of tree species (Cliffe et al., 2023), but other factors should be considered.

### Sloth admission seasonality

Annual admission data show that sloth rescues occur year-round, with the lowest numbers between April and June and two clear peaks in December–January and July–August. By species, the pattern is similar, although peaks occur slightly earlier for CH (July and December) compared to BV (August and January) (Fig. 2a).



**Fig. 2.** Temporal trends in sloth admissions (*Choloepus hoffmanni*, CH, and *Bradypus variegatus*, BV). (a, top) Annual admissions showing seasonal peaks by species; (b, bottom) Yearly trends of admissions (2012–2022), including declines in 2018 and 2020.

These peaks likely correspond to school and holiday breaks, which increase both local and international travel. The December-January spike aligns with the extended Christmas/New Year's vacation and the beginning of the dry season, when many tourists arrive. The July-August peak aligns with the mid-year school holiday in Costa Rica and summer vacations abroad, during which domestic travel and tourism rise substantially. Increased human activity during these holiday periods may lead to more sloths being noticed, injured, or otherwise entering rescue networks (e.g., via road crossings, increased encounters or disturbances near tourist infrastructure).

Yearly trends indicate consistent growth in rescues for both species, with CH comprising 60–70% and BV 30–40% in most years. This increase is partly explained by the establishment of new WRCs and the rapid rise of rescues in the South Caribbean, which reached 268 individuals

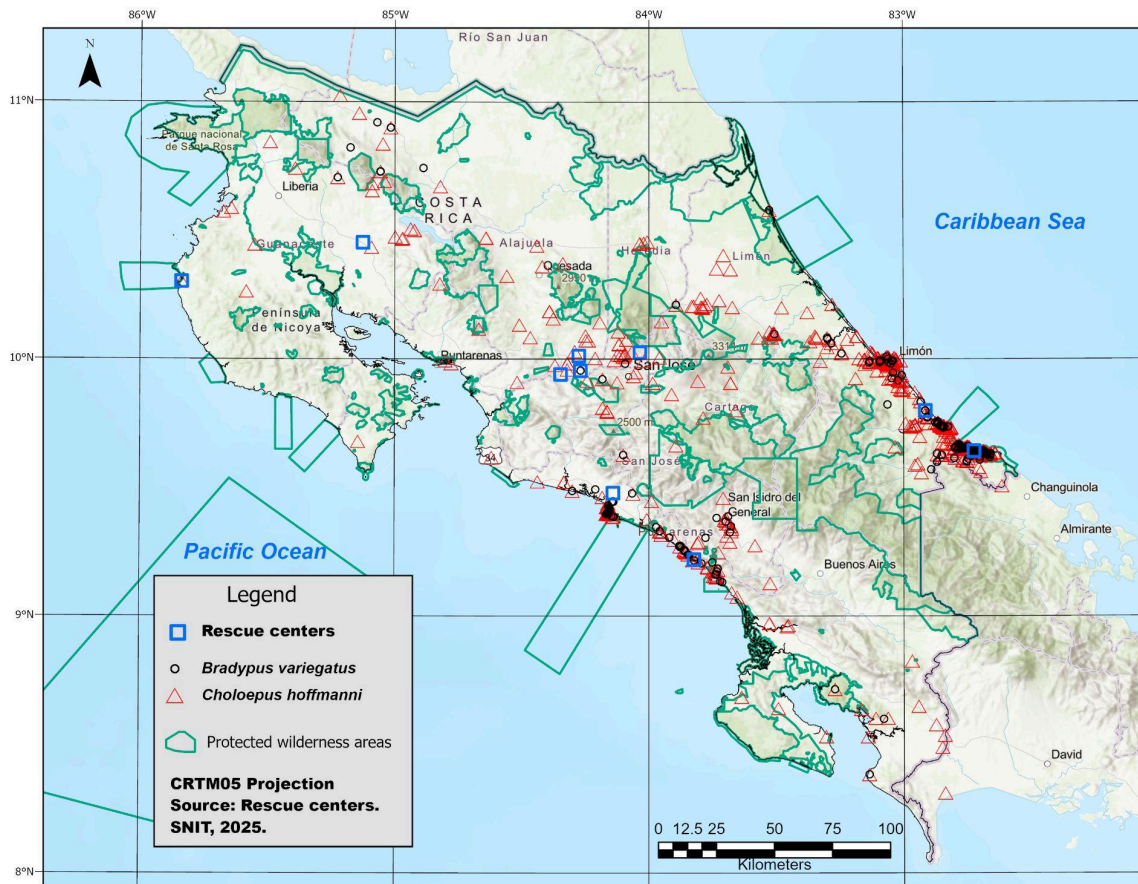
across two centers in 2022 (74% of the total). The growth curve also shows two declines: in 2018, due to data loss from the center with the highest contributions, and in 2020, likely related to the COVID-19 pandemic, which reduced tourism and restricted movement (Fig. 2a, Fig. 2b).

All years presented a positive increase in sloth admissions, except for 2020, which showed a 5.6% decline linked to the effects of COVID-19. During the last five years of the study period (2018 to 2022), the average annual growth rate was 8.7%. This trend does not necessarily reflect an increase in the overall sloth population. Instead, it suggests that the drivers of rescues, such as the continued expansion of human settlements, infrastructure development, and tourism in forested but unprotected areas, have intensified over time.

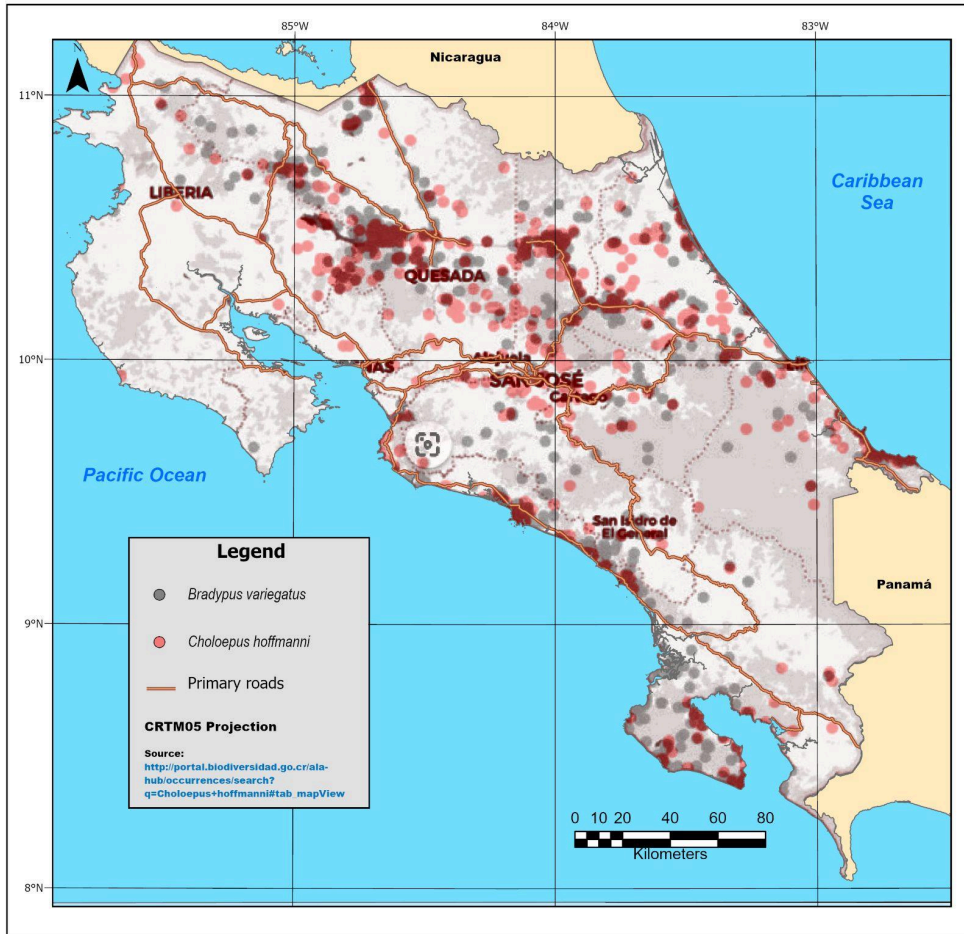
### **Sloth species geographical and altitude distribution**

The data from rescue locations are not fully representative of the actual distribution of sloth populations in Costa Rica. However, given the limited amount of published ecological data available, they still provide valuable insights into the areas where sloths are present. To complement our analyses, we compared our data with observation records from the Sistema Nacional de Información sobre Biodiversidad de Costa Rica (SINAC/INBio), accessible through the national data included in the Global Biodiversity Information Facility portal, GBIF (SNIB-CR, 2023a; 2023b). Although these records are not peer-reviewed publications, they compile validated citizen-science observations and their geolocalization, offering valuable context for comparing admission localities with the known distribution of both sloth species. This review documents 4822 observations, 2,163 of CH and 2,659 of BV, primarily contributed by the general public through citizen-science initiatives.

Comparing both datasets (Fig 3 and Fig 4), we identified shared hotspot areas, including San José, San Carlos, the central Pacific coast, Guápiles, and the southern Caribbean. In contrast, some regions presented very high numbers of observations but few recorded rescues, such as Monteverde and Arenal, Corcovado, Sarapiquí, and Tortuguero. These locations are mostly within national parks and other tourism-driven protected landscapes.



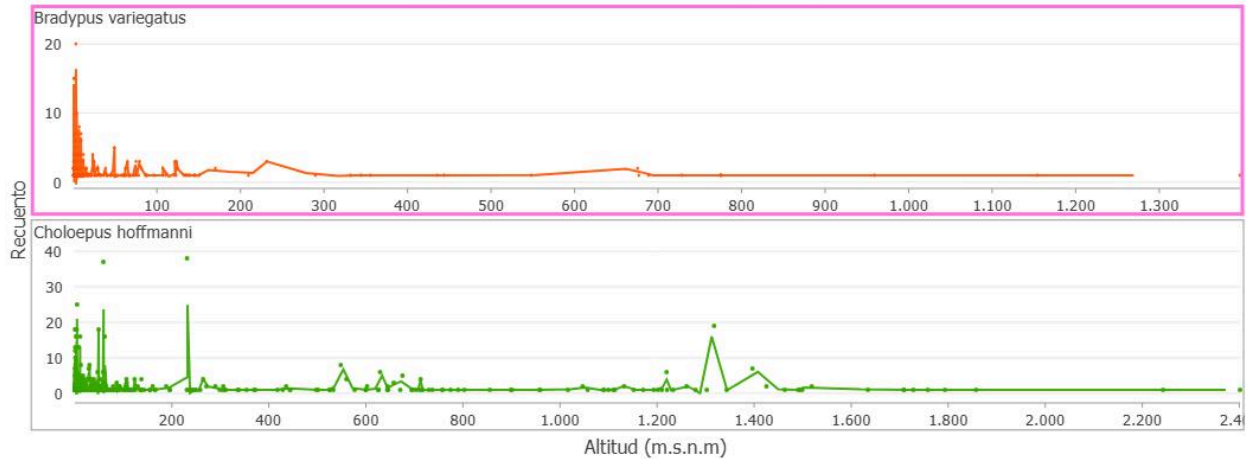
**Fig. 3.** Map of Costa Rica with distribution of sloth rescues (*Choloepus hoffmanni* and *Bradypus variegatus*), rescue centers, and protected wilderness areas, according to data obtained during the period 2012-2022.



**Fig. 4.** Map of Costa Rica with distribution of sloth observation from the citizen-reported data included in the Global Biodiversity Information Facility portal, GBIF portal (SINAC/INBio).

The central Pacific and the central and southern Caribbean show high densities of both observations and rescues, despite limited formal protection and intense human activity. This comparison suggests that sloths in national parks are less likely to need rescue, while populations in human-dominated landscapes face greater risks. Moreover, areas such as the central and northern Caribbean lack nearby rescue centers, underscoring the need for expanded rescue coverage and targeted community sensitization in these high-impact zones. Data highlights the very low number of both observations and rescues from the Nicoya Peninsula, in the northern part of the country, where rescue data shows that species are present but extremely scarce.

Analysis of rescue altitudes revealed distinct species-specific patterns, with BV rescues taking place in lower altitudes than CH (Fig. 5). Most BV rescues occurred below 100 m, with fewer than 10 cases recorded between 600–1,200 m and none above this elevation. In contrast, CH showed a broader elevational range: while the majority of rescues were also below 200 m, more than 60 cases were recorded above 600 m, reaching a maximum of 2,400 m.



**Fig. 5.** Rescue altitude ranges showing by sloth species during the period 2012-2022.

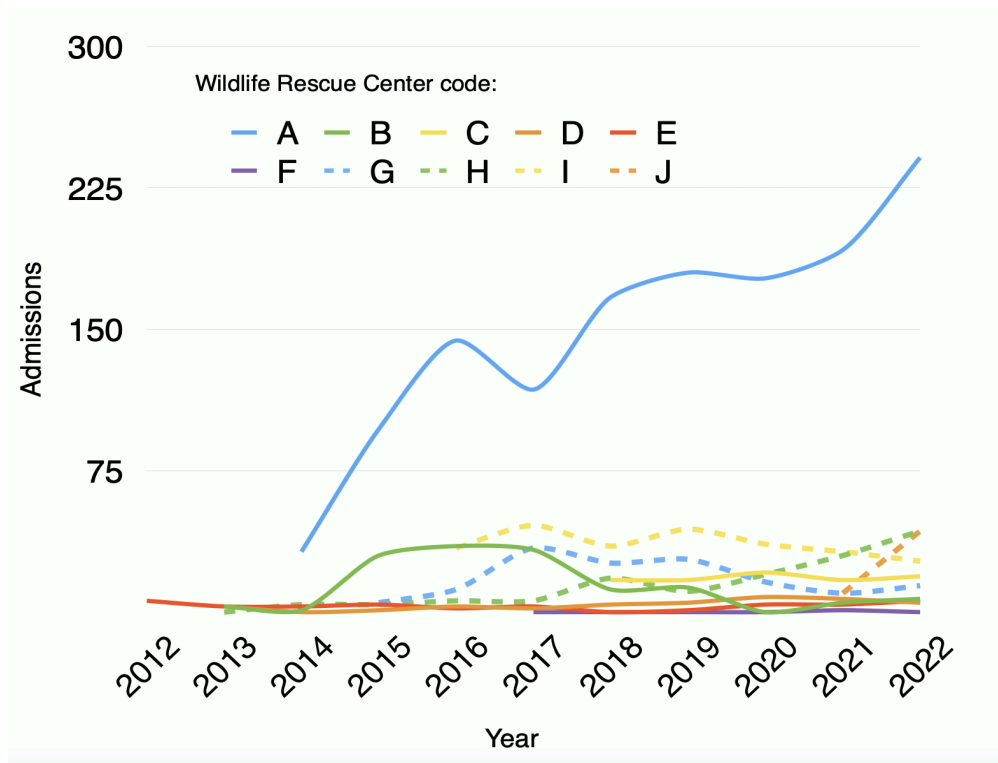
In terms of overall distribution, while precise population estimates for these species are limited, CH were recorded throughout the country. However, they were scarce in the Nicoya Peninsula and at elevations above 2,400 m. In contrast, BV showed even lower presence in the Nicoya Peninsula and the northern central region, with its distribution concentrated mainly in the coastal lowlands.

CH and BV occupy humid tropical and premontane forests from lowland areas up to approximately 2,500 m (*B. variegatus*; IUCN, 2022) and even up to 3,300 m (*C. hoffmanni*; Superina et al., 2010). Both species utilize forested habitats and agroforestry landscapes such as shade-grown cacao, although only CH appears capable of sustaining viable populations in these matrices, while BV shows greater dependence on continuous canopy cover (Vaughan et al., 2007; Peery & Pauli, 2014). Recent work in the lowland Caribbean rainforest further documents both species' activity within this ecosystem, reinforcing their reliance on humid forest structures for movement and resource use (Cliffe et al., 2023). Observations from Braulio Carrillo National Park confirm that both species are present above 2,400 m, indicating overlap across elevation gradients (te Beek, 2018).

These ecological patterns provide a baseline for comparison with the admission localities in our dataset, allowing us to assess whether rescues reflect known habitat use or point to emerging risk areas outside typical ranges.

## Rescue centers and overall admissions

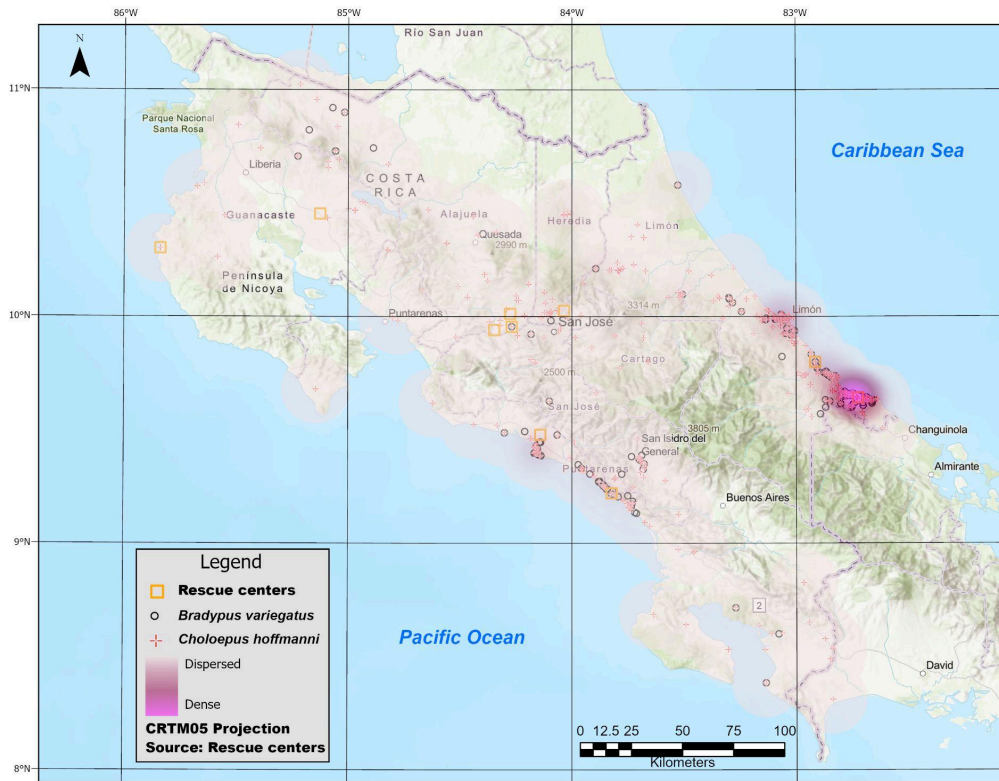
All ten collaborating centers received sloths during the study period, but admissions were highly uneven across regions. Results presented in Figure 6 show a steady and moderate number of admissions across most centers, with an overall average of 31.8 sloths per year. The central region (centers B, E, H, J) admitted 320 sloths (14.2% of all cases, averaging 11.4 per year), most of them *C. hoffmanni* (91%). The two Central Pacific centers (A, I) received 284 sloths (16 per year on average), with a species distribution similar to the South Caribbean (CH: 60.9%, BV: 39.1%). In the northern region, the two centers reported different numbers. In the center D, located in Liberia, 38 sloths were admitted, again mostly CH (89.5%), while the center F, in the Nicoya Peninsula, received only one sloth over five years.



**Fig. 6.** Distribution of admissions among Costa Rican rescue centers during the period 2012-2022.

By contrast, the South Caribbean region (centers C, G) dominated admissions, with 1,602 sloths in total. The center G alone accounted for 60% of all cases in the study, averaging 148.8 per year, which is 4.7 times higher than the average of the other centers combined, while the center C contributed 11.3%. When focusing only on the last two years of the study, center G averaged

203.3 admissions per year, compared to 36.9 across all centers, a 5.5-fold difference. GIS mapping of admission hotspots and their progression over time further highlights the South Caribbean as the region with the most dramatic increase in rescue activity (Fig. 7).



**Fig 7.** Costa Rican density hotspot areas of sloth admissions, species distribution, and rescue center locations.

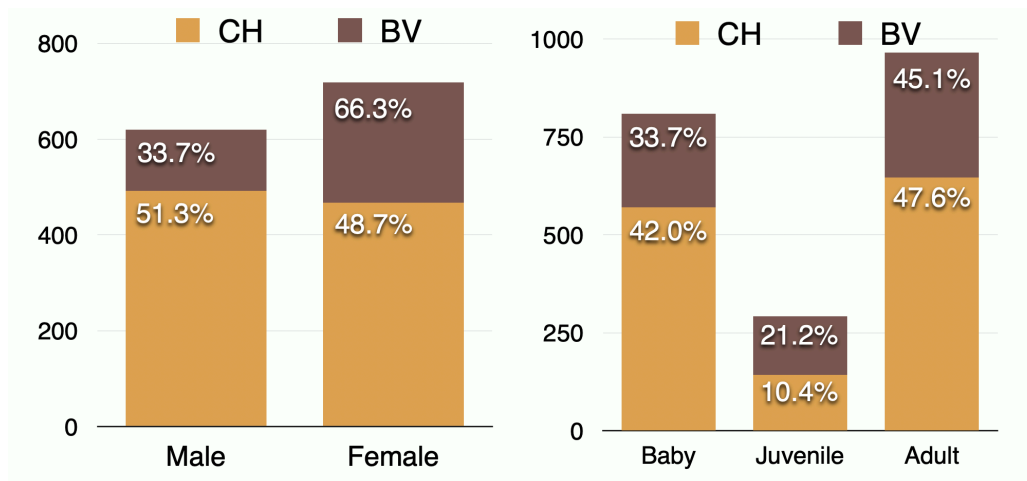
This striking concentration of cases in the South Caribbean likely reflects several interacting drivers. The area has experienced sustained tourism growth and the expansion of hotels and residential developments outside the main urban nucleus of Puerto Viejo, often embedded in or adjacent to forested habitats where sloths remain common (Quesada Avendaño, 2016). Such landscape changes increase the likelihood of human–wildlife interactions, resulting in more sloths entering rescue networks.

Survival outcomes also varied notably among centers. For example, in relation to electrocution cases, one center achieved a survival rate of 44.5% with an average rehabilitation time of 137 days. In contrast, another reported only 11.5% survival, with an average stay of 26 days. While

these differences highlight variability in rehabilitation results, the aim of this study is not to compare protocols among individual centers but to provide an overall perspective on admissions and outcomes.

### Age and gender:

Sex was identified for 1,339 individuals, with 51.3% males and 48.7% females in CH, and 33.7% males and 66.3% females in BV. The higher number of BV females compared to CH may be partly explained by the greater difficulty of sex determination in this species (Fig 8a). Males can be distinguished from females by the presence of a dorsal orange-yellow patch with a broad black central stripe (Hayssen, 2010), although this feature is much harder to identify in juveniles. In contrast, although CH lack this patch, they exhibit more prominent genitalia than BV, which facilitates sex identification.



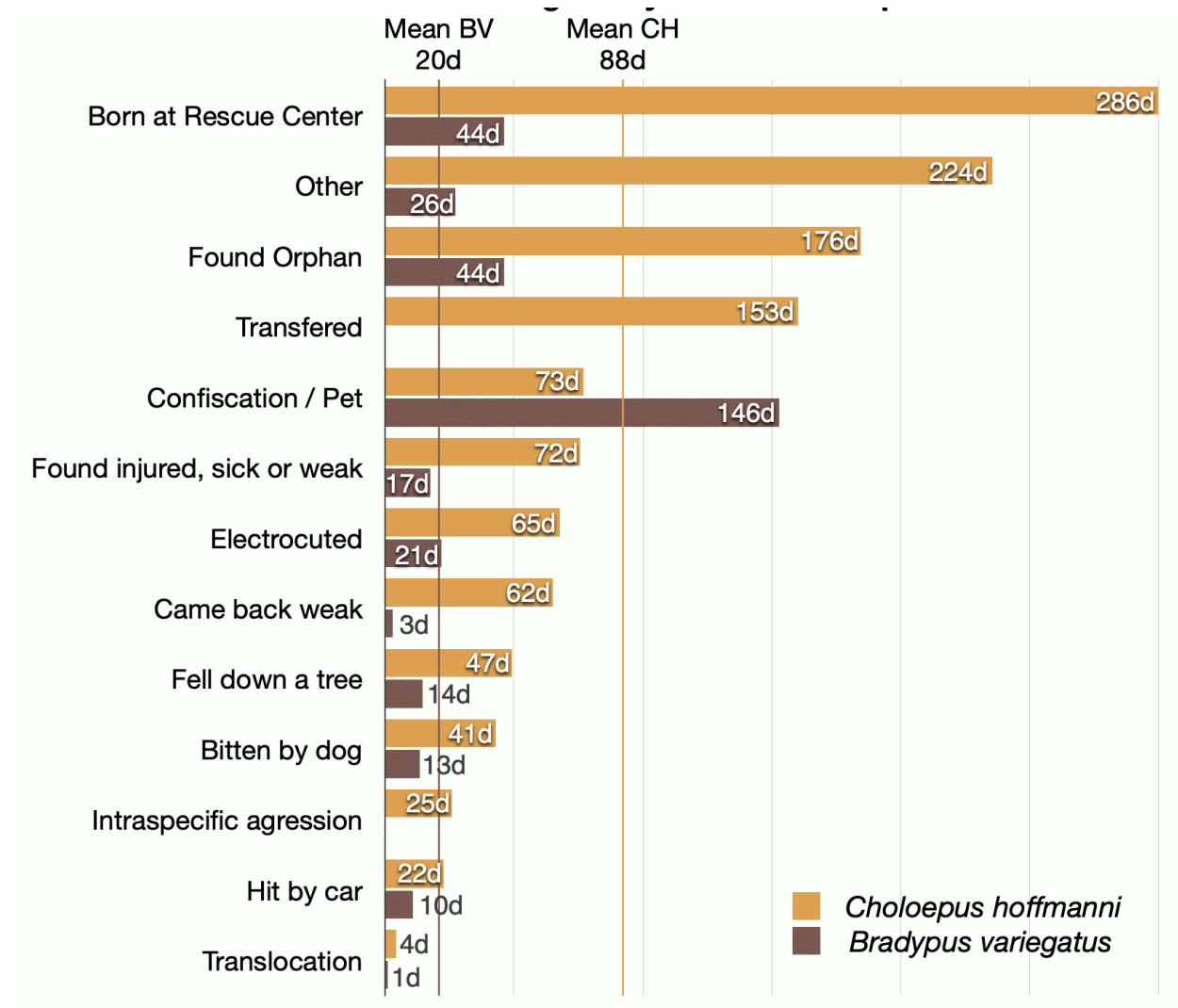
**Fig. 8a.** Sex ratios of admitted sloths. **8b.** Age distribution of admitted sloths (babies, juveniles, adults).

Age data were available for 2,067 cases (Fig. 8b). The percentage of adults was similar between species, but CH had a higher proportion of babies than BV (CH: 41.6% vs. BV: 34.1%). It should be noted that the criteria for distinguishing babies from juveniles vary among rescue centers, which may influence these proportions. According to the consulted centers, baby CH were defined as individuals ranging from approximately 300 g to nearly independent weights of about 1.8 kg; above this range, they were generally classified as juveniles. BV newborns weighed about 200 g, with some premature cases as small as 150 g, and were considered independent at around 1.5 kg. Despite being born smaller, three-toed sloths spend less time with their mothers

and reach independence at an earlier stage (Zacharias et al., unpublished data; Britton, 1941; Montgomery & Sunquist, 1978; Eisenberg & Maliniak, 1985).

### Days in the center:

We analyzed the length of stay at WRCs for each admission cause and species among 1,836 individuals with recorded resolution and exit dates. The results indicate that WRCs generally rehabilitate BV for significantly shorter periods than CH. On average, BV undergoes rehabilitation for 20 days, while CH remains in care for 88 days (Fig. 9).



**Fig. 9.** Length of stay in rehabilitation by sloth species, according to cause of admission to rescue centers.

Additionally, BV typically dies sooner than CH in captivity across most admission causes. On average, CH dies after 42 days, whereas BV dies after 28 days. These findings highlight the considerable economic and human resources required per rescued individual, underscoring the financial and logistical impact on wildlife rescue centers.

### Distance from rescues to the wildlife rescue center (WRCs)

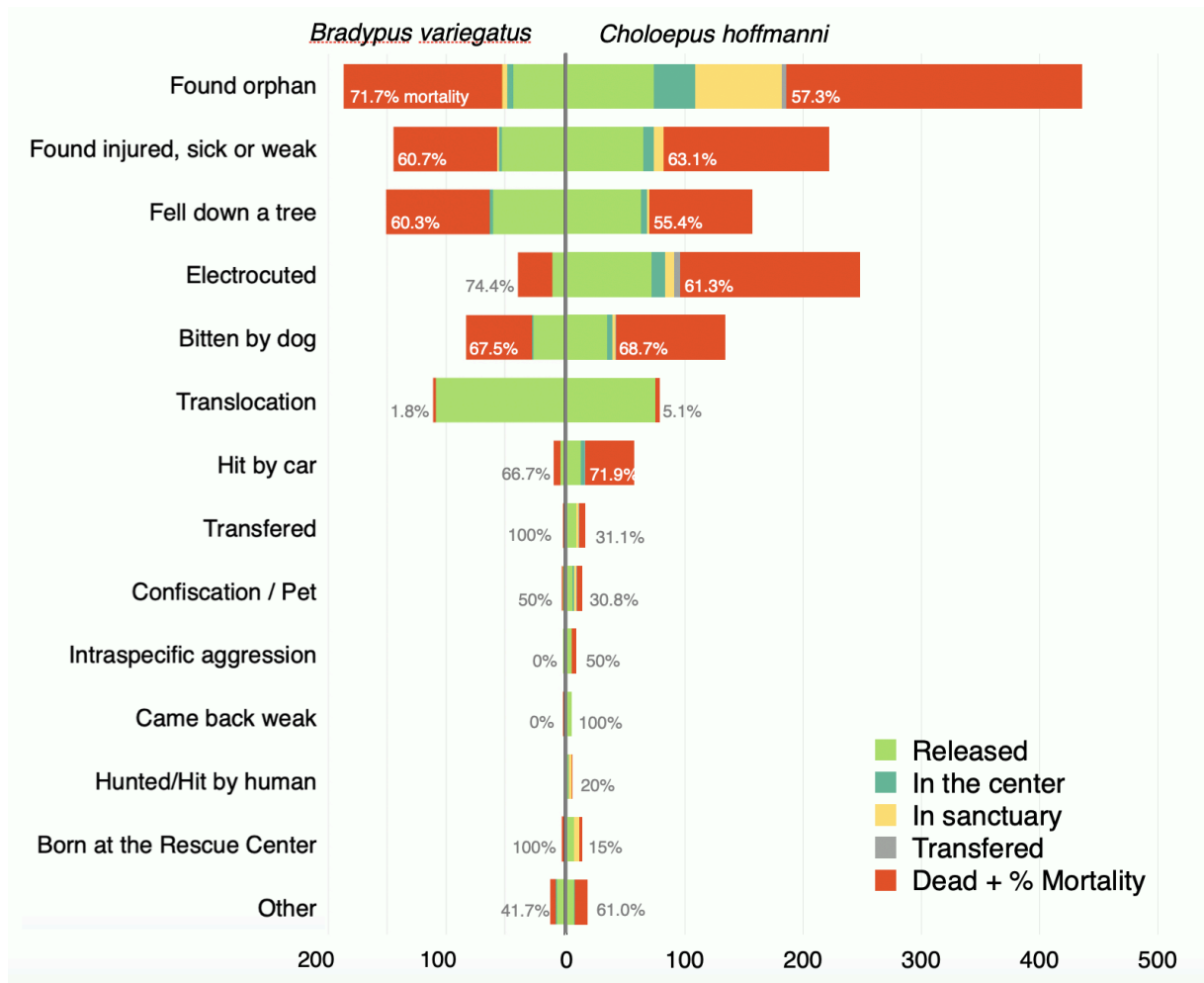
Distances from rescue sites show a clear association with the location of the WRCs. Centers situated in coastal, tourism-oriented areas (A, B, I, G) receive sloths from shorter distances, often under 30 km on average, since most rescues are carried out locally by the centers themselves. In contrast, inland centers (D, H, C, E, J) report substantially longer average distances, in some cases exceeding 100 km. This pattern suggests that inland centers rely more heavily on rescues conducted by external institutions such as firefighters or SINAC, with animals transported from broader areas rather than rescued directly by the centers. Center F was excluded from this analysis because it only had a single record (n=1) (Table 1).

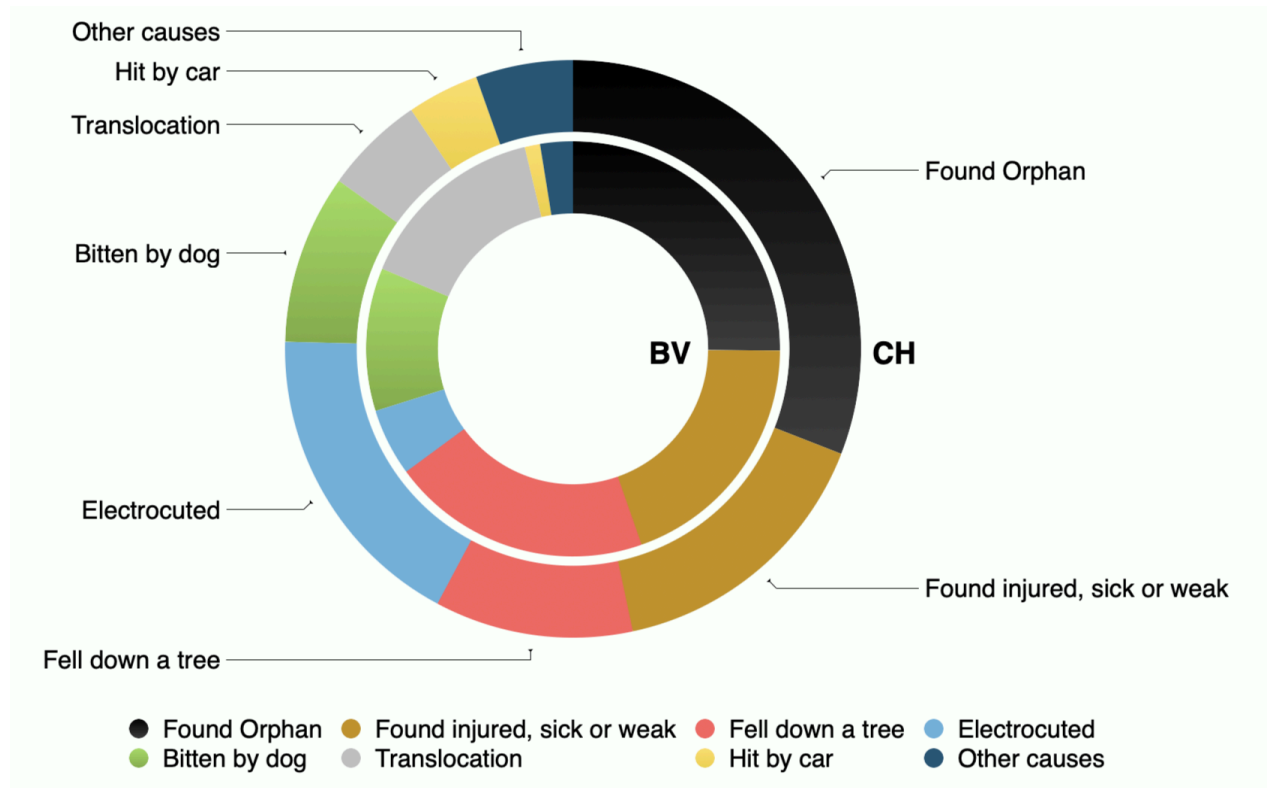
WRC	Mean Distance (km)	Median Distance (km)	Location
A	11.8	3.6	Coast
B	19.0	8.5	Coast
I	26.2	20.3	Coast
D	33.6	30.0	Inland
G	36.7	19.2	Coast
H	37.7	40.1	Inland
C	46.8	28.9	Inland
E	82.9	68.7	Inland
J	113	128	Inland
F	-	-	-

**Table 1.** Mean and median distances of sloth rescues according to wildlife rescue centers (WRC) where they were admitted during the period 2012-2022.

## Admission Cause Analysis

Of the 2,247 total entries, 2,180 cases included data on cause of admission, and 2,154 had information on both cause and outcome. The seven leading causes accounted for 95.6% of all situations were: 1) found orphaned (28.9%), 2) found injured, sick, or weak (17.0%), 3) fell from a tree (14.3%), 4) electrocution (13.3%), 5) dog attack (10.1%), 6) translocation (8.8%), and 7) vehicle collision (3.1%) (Fig. 10a).

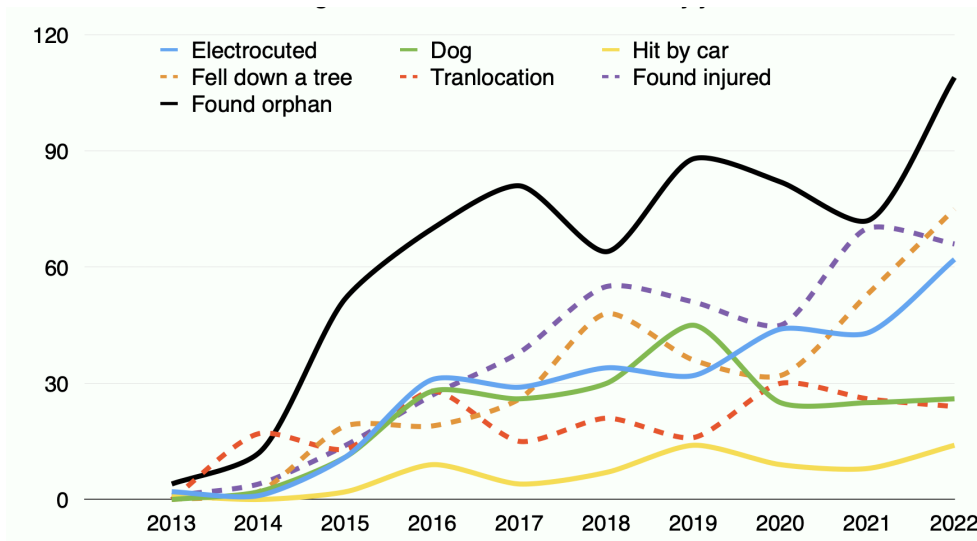
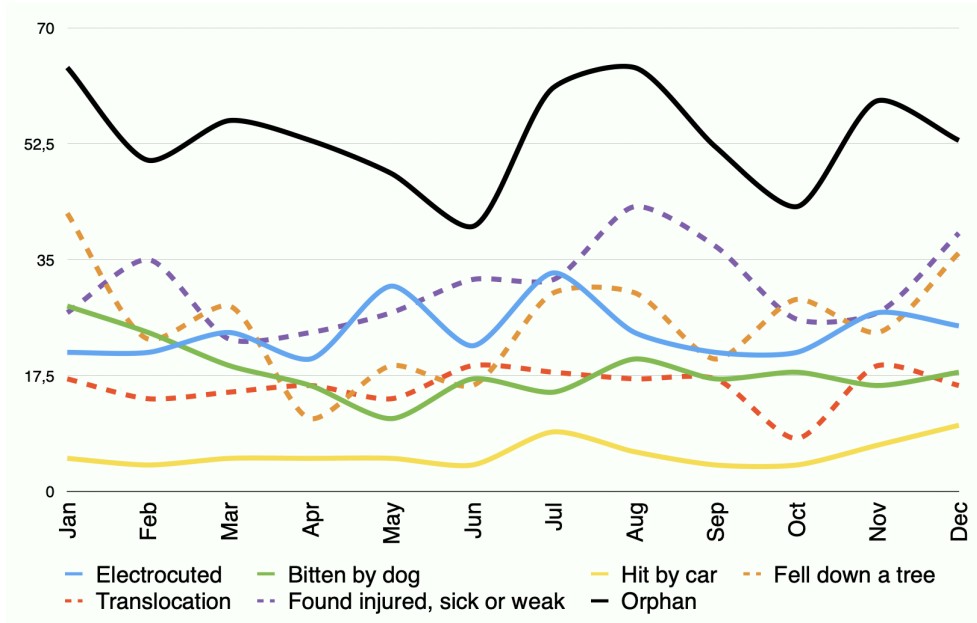




**Fig. 10.** Causes of admission in sloths to Costa Rican wildlife rescue centers. **(a, top)** Admission causes by species and their outcomes; **(b, bottom)** leading admission causes according to sloth species (*Bradypus variegatus* -BV- and *Choleopus hoffmani* -CH-).

When comparing species, being orphaned was the primary cause of admission for both. Electrocuttions were notably higher in CH (17.6%) than in BV (5.2%), ranking as the second most common cause for CH. In contrast, falling from trees was more frequent in BV (20.1%) than in CH (11.1%). Vehicle collisions also showed species differences, occurring more often in CH (4.0%) than in BV (1.2%). Finally, translocations were proportionally more common in BV (14.8%) than in CH (5.5%) (Fig. 10b).

The temporal trends for each cause of admission are presented in Figures 11a and 11b below, and their analysis is provided in the corresponding sections for each cause of admission.



**Fig. 11.** Temporal trends for each cause of sloth admission to wildlife rescue centers. **(a, top)** Monthly admissions by cause; **(b, bottom)** annual trends in admission causes since 2013 to 2022.

### Causes of admission: Found orphan

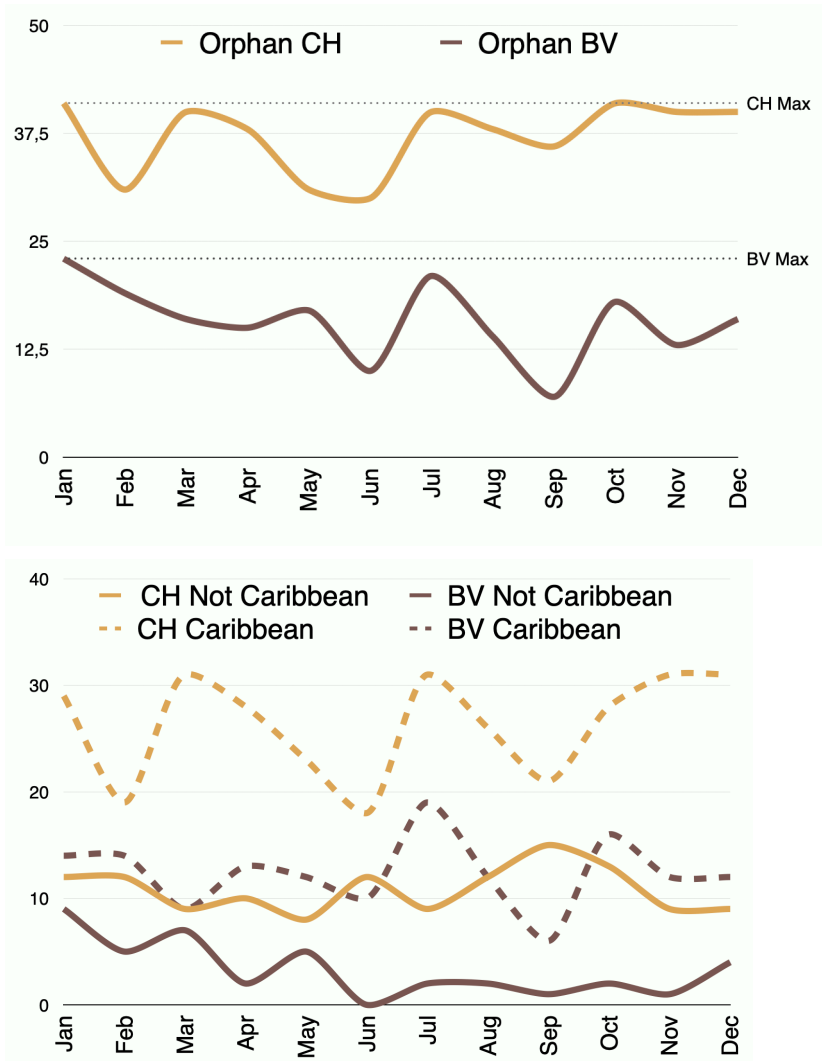
A total of 635 sloths (29.1%) were admitted as orphans, making this the primary cause of admission for both species. CH accounted for most cases ( $n=446$ , 70.2%), while BV represented 29.8% ( $n=189$ ) (Fig. 10a, 10b).

Our results indicate that BV is significantly more challenging to raise in captivity than CH. Overall, 61.6% of orphaned sloths did not survive rehabilitation, with BV experiencing a higher mortality rate (71.7%) compared to CH (57.3%). CH also demonstrated a higher survival rate (42.7%) than BV (28.3%). Time under rehabilitation further supports this pattern, as CH remained in care nearly four times longer than BV (Fig. 8). This pattern may reflect the tendency of WRCs to release BV at a younger age, combined with their higher early mortality. In contrast, CH are retained longer due to their extended juvenile dependency period (Britton, 1941; Montgomery & Sunquist, 1978).

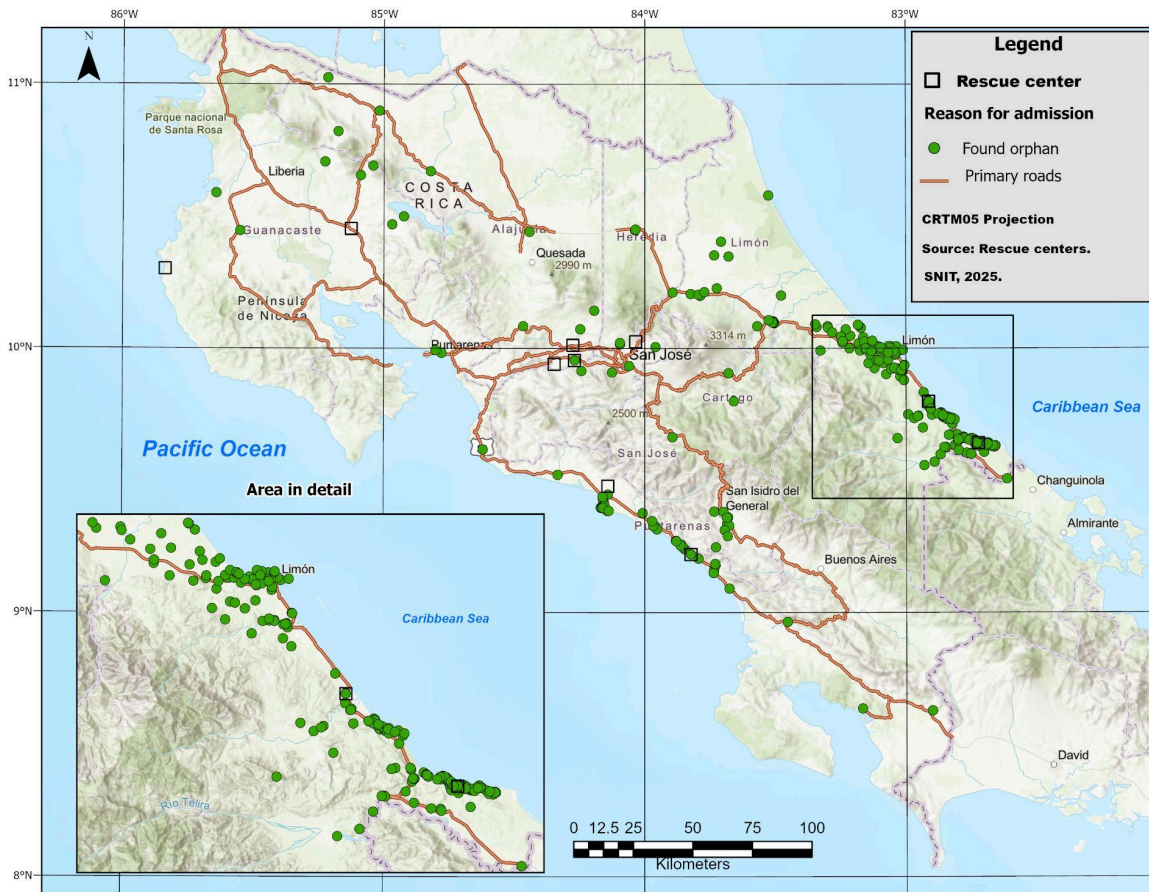
Previous studies have documented a higher prevalence of respiratory diseases in young *Bradypus* sp. separated from their mothers compared to *Choloepus* sp. (Santos, 2023). Other commonly reported health issues include milk maladaptation, diarrhea, bloat, and fecaloma (Messias-Costa, 2001; Dünner & Pastor, 2017). These factors, combined with species-specific differences in dependency and resilience observed in wild populations (Hayssen, 2010; Veselovsky, 1966), likely explain the greater difficulty in raising BV compared to CH.

When considering age at admission rather than cause, we recorded 796 juvenile admissions. This discrepancy arises because 166 neonates were classified under alternative causes at the time of admission (see Age and gender section).

Regarding seasonality, our data indicate that orphaned sloths are admitted year-round, with peak admissions occurring in January, July, and October. CH exhibited an additional peak in March and April (Fig. 12). When analyzing data separately for two South Caribbean rescue centers, we observed notable seasonal differences (Fig. 13). In this region, BV admissions fluctuated year-round, peaking in July, whereas in the rest of the country, admissions peaked in January, followed by a gradual decline until May, with minimal admissions for the remainder of the year. This pronounced seasonality aligns with previous research on sloth reproductive biology in Costa Rica. Peery & Pauli (2014) documented seasonal breeding in a shade-grown cacao farm, with births peaking in late February. Vaughan et al. (2011) reported two birthing seasons in the Caribbean side, occurring between November and December (coinciding with the end of the long rainy season) and April to May, while also noting that reproductive timing in sloths can be irregular and climate-dependent.



**Fig. 12.** Seasonal patterns of sloth orphan admissions to Costa Rican wildlife rescue centers during the period 2012-2022. **(a, top)** Seasonal patterns by species; **(b, bottom)** regional differences in orphan seasonality, comparing Caribbean rescue centers with the rest of the country.



**Fig. 13.** Geographic distribution of sloth orphan cases reported in Costa Rica from 2012 to 2022.

Additionally, fluctuations in admission rates may be influenced by Costa Rica’s tourism seasonality. Tourism peaks from December to April, particularly during Christmas (December–January) and Easter (March–April), with a secondary increase in July–August due to international visitors.

The observed differences in rehabilitation time between species can also be attributed to developmental differences. BV juveniles typically achieve independence earlier (6–9 months) than CH juveniles (9–12 months), particularly in captivity (Hayssen, 2010; Meritt, Jr., 1985; Partridge, 1991; Veselovsky, 1966). This well-documented difference, widely recognized by rescue centers, likely explains why BV orphans have shorter rehabilitation periods and can be released sooner than CH orphans.

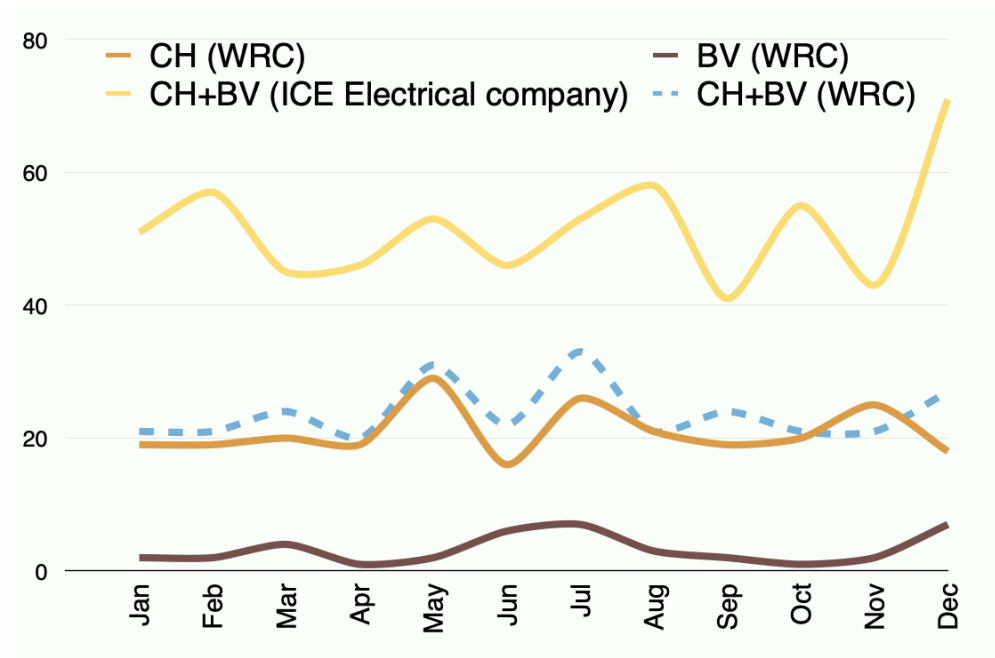
The geographic distribution of orphan cases did not reveal distinct hotspots, largely mirroring the overall spatial pattern observed for all admission causes (Fig 13).

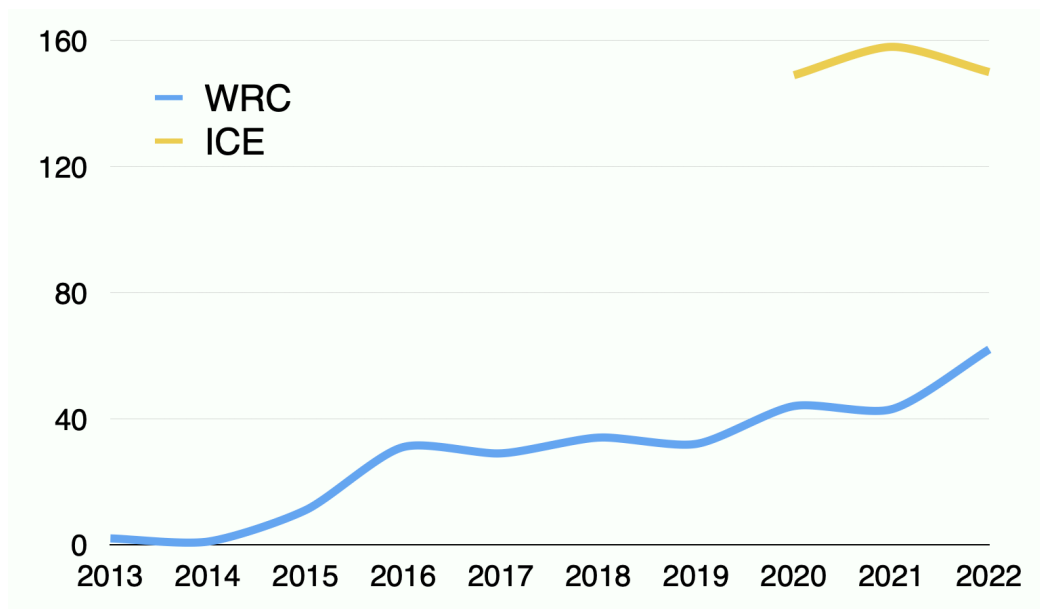
Our study provides new insights into the admission patterns of orphaned sloths in Costa Rica, highlighting species-specific differences in survival rates, release timelines, and seasonal admission trends. These findings emphasize the greater challenges in rehabilitating BV and suggest that rescue centers should consider species-specific strategies for improving rehabilitation success. Future research should investigate the ecological and environmental factors influencing birth seasonality and mortality in wild populations to inform conservation efforts.

### Causes of admission: Electrocutions

Electrocution was the leading anthropogenic cause of mortality for sloths, accounting for 290 admissions across the ten WRCs. Predominantly, it affects CH (86.5%) over BV (13.4%). It resulted in an overall mortality rate of 63.1%, with CH at 61.3% and BV at 74.4%. The relative impact of electrocution was notably higher for CH, ranking as the second most common cause (248 individuals, 17.6% of all CH cases), while for BV it was the sixth cause, accounting for only 39 animals (5.2% of all BV cases).

The actual impact is likely higher, since many sloths may die before reaching rehabilitation facilities. To better understand the scope of the problem and assess seasonal trends, we compared our data with records from the Costa Rica’s primary electrical company (ICE), which provided a database of sloth electrocution cases spanning four years (July 2019 – July 2023) (Fig 14a).





**Fig. 14.** Season patterns of electrocution admissions. **(a, top)** Comparison of wildlife rescue center (WRC) electrocution records by species with the Costa Rica’s primary electrical company (ICE) data. **(b, bottom)** Annual trend of electrocution admissions comparing WRCs and ICE data.

ICE recorded 619 sloth electrocutions. Seasonality analysis (Fig 14b) indicates that events occur year-round without marked monthly differences. While ICE’s dataset did not differentiate species, the WRC data revealed distinct patterns: CH showed mild increases in May, July, and November, whereas BV peaked in June, July, and December. Results from ICE indicate that the company registers about 2.5 times more electrocutions per year than the ten WRCs combined.

Comparing geographic distributions, shared hotspots included the central and south Caribbean, the central Pacific coast, and the metropolitan area. However, ICE also reported substantial electrocution numbers in central-northern Caribbean and the central and south Pacific, where few rescues were recorded. These discrepancies highlight the lack of rescue capacity in specific regions and underscore the need to expand rescue networks (Fig 15).

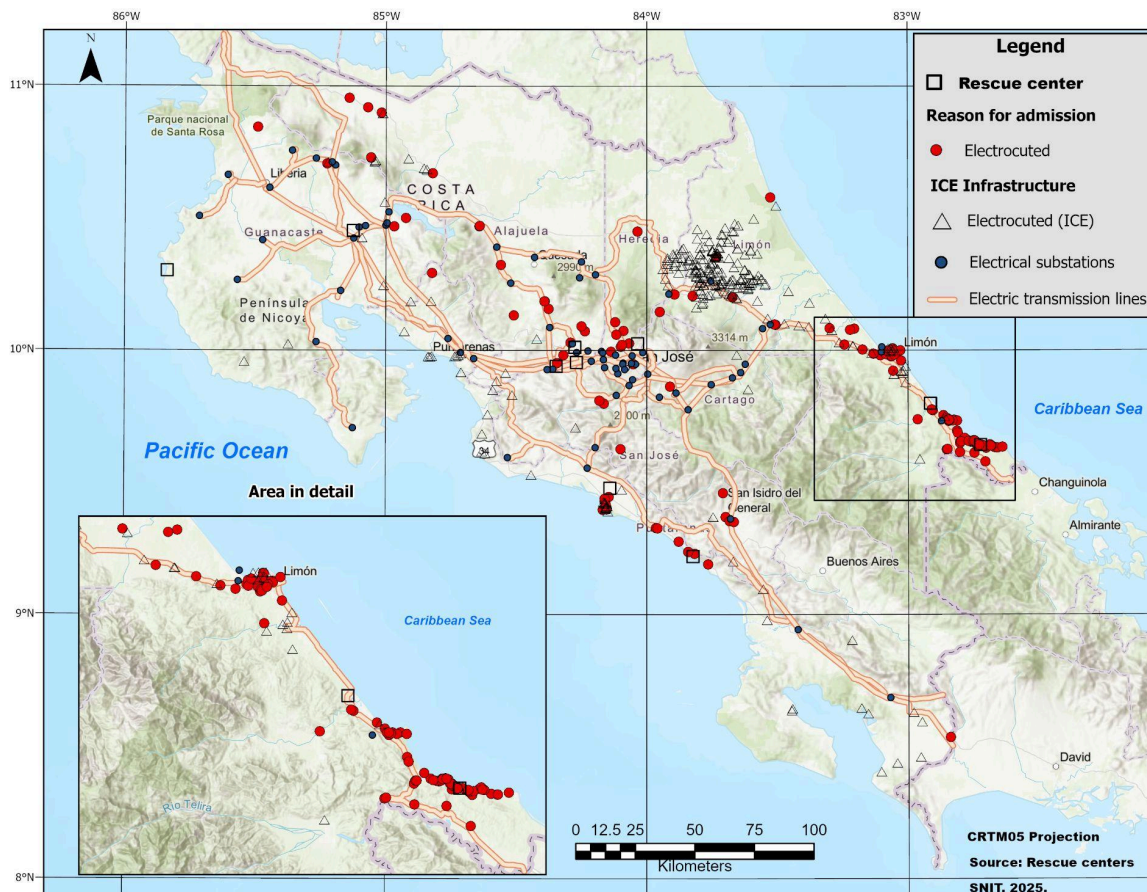


Fig. 15. Geographic distribution of electrocution cases, showing wildlife rescue center (WRC) rescue records alongside Costa Rica's primary electrical company (ICE) data and infrastructure.

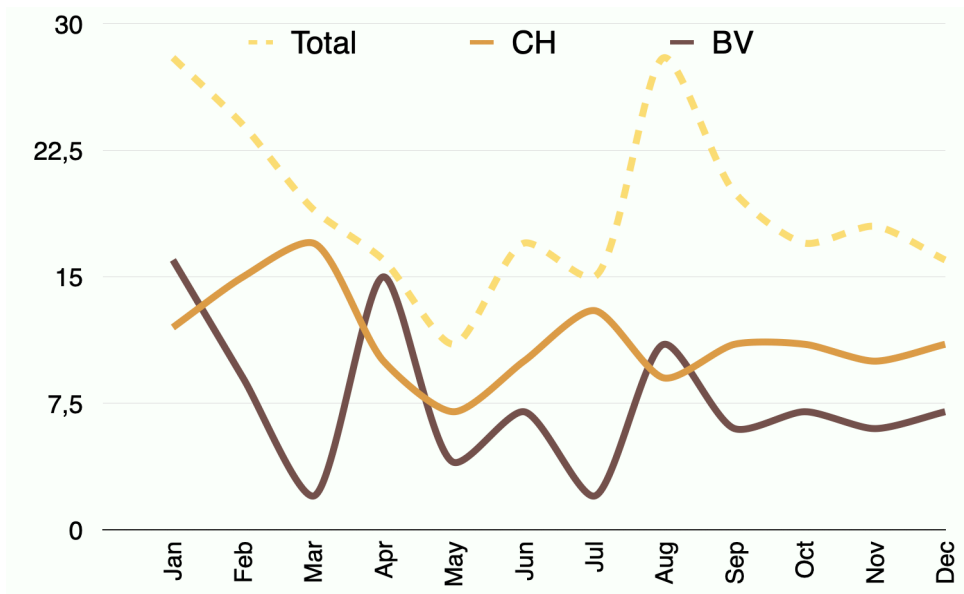
Overall, our findings indicate that electrocution represents a greater threat to sloth populations than previously estimated from WRC data alone. This highlights the urgent need to reinforce mitigation efforts (i.e. insulating power lines or establishing safe canopy crossings). Priority should be given to the three hotspot regions where rescues are scarce but ICE reports high numbers of electrocutions.

Survival rates following electrocution were significantly higher for CH than for BV (38.7% vs. 25.6%) (Fig. 10a), suggesting that BV are more vulnerable to electrocution and that their rehabilitation is especially challenging compared to other causes. Electrocution is a well-recognized global threat to arboreal mammals, driven by expanding urbanization, and can cause injuries of varying severity (Almeida et al., 2022; Carmo et al., 2019). For sloths, which depend entirely on arboreal pathways for movement, these risks carry particularly severe consequences.

Our research indicates that *Choloepus* sloths experience higher electrocution rates than *Bradypus* sloths in Costa Rica, likely due to behavioral and ecological differences. Two-toed sloths are more mobile, change trees more frequently, and descend to the ground more often to cross fragmented habitats, all of which increase their risk of contacting power lines. In contrast, *Bradypus* sloths tend to move less, remain in the same area for extended periods, and display lower activity levels (Sunquist & Montgomery, 1973; Chiarello, 2008; Peery & Pauli (2014). This greater mobility likely contributes to the higher incidence of electrocution observed in our study, a pattern consistent with findings from Brazil that also link intergeneric behavioral differences to electrocution risk (Santos et al., 2023).

### Causes of admission: Dog Bites

Dog bites were the fifth most frequent cause of admission in WRCs, with 219 cases (10.1%). Their relative importance was comparable between species, ranking fifth for both (CH: 9.5%, BV: 11.2%). Dog bites accounted for the second-highest mortality rate among sloths (68.2%), surpassed only by vehicle collisions. Mortality rates did not differ significantly between species (CH: 68.7%, BV: 67.5%) (Fig. 10). Peaks in incidents were observed in January and August, but also occurred intermittently throughout the year. These peaks coincide with tourist seasons along the coasts, where most bite cases were recorded (Fig. 16).



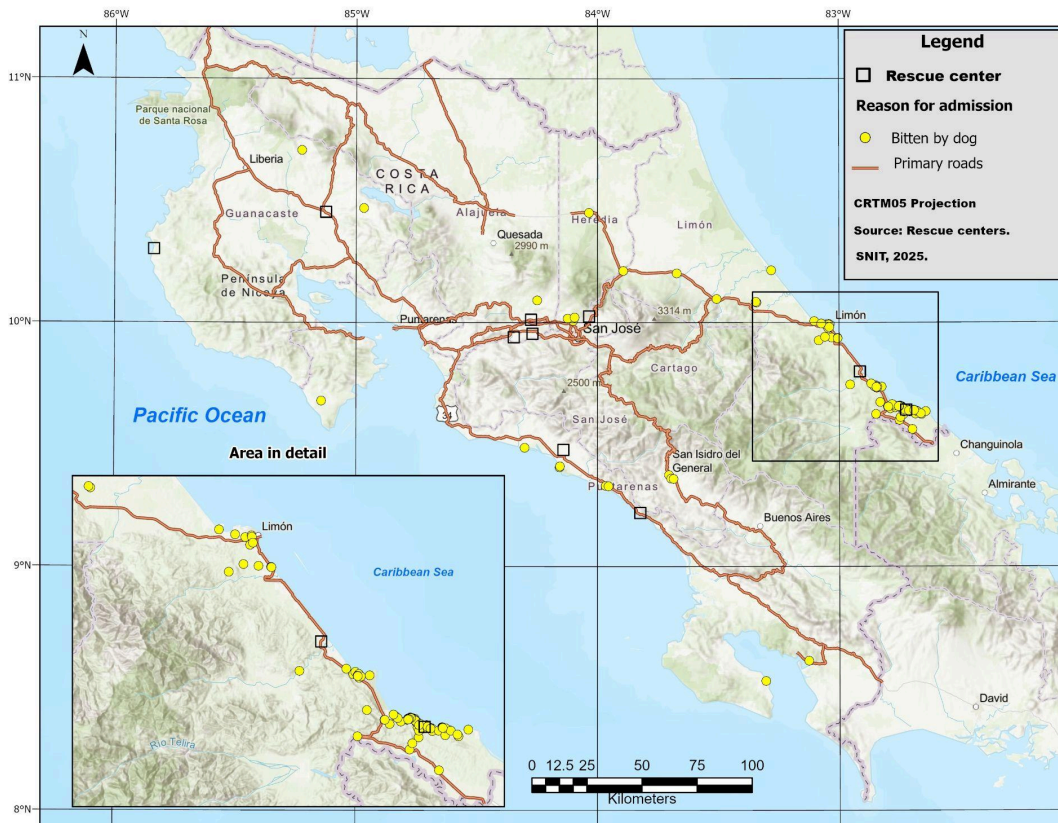
**Fig. 16.** Seasonal patterns of admissions to wildlife rescue centers of sloths bitten by dogs.

In the Caribbean, urbanization and agricultural expansion have contributed to deforestation and the conversion of land to treeless pastures, placing sloths at a distinct disadvantage. The absence

of trees forces sloths to traverse the ground, exposing them to predators and disrupting natural corridors along streams, fencerows, and plantations. This vulnerability is particularly evident when sloths rest in dense grass within humid pastures, where they become more susceptible to predation by dogs. The importance of living fencerows as feeding and travel corridors underscores the potential consequences of their loss or temporary unavailability (Vaughan et al., 2007).

Recent case reports further illustrate the severity of this threat. Brown et al. (2023) described a *C. hoffmanni* that sustained fatal polytraumatic injuries from a dog attack, while Peery & Pauli (2014) found that predation by coyotes and domestic dogs was the leading cause of mortality among adult sloths near a cacao farm. In response, local initiatives in Costa Rica have sought to mitigate domestic dog attacks through community education and canine training, though these efforts require nationwide expansion. Comparable programs in India, focusing on responsible ownership and dog population control, have reduced dog-wildlife conflict (Home et al., 2017).

The geographical distribution reveals a disproportionately high number of cases in central and south Caribbean. Additional cases were recorded in the central Pacific and in the metropolitan area, but the strongest hotspots were concentrated along the Caribbean coast (Fig 17).



**Fig. 17.** Geographic distribution of dog attack cases.

In the country, dog ownership is widespread, with 76% of households owning at least one dog and an average of 1.4 dogs per household (Flockhart, Rowan, & Boone, 2022). Many of these animals are only partially confined, which increases their potential contact with wildlife. Research from Columbus, Ohio, further suggests that higher concentrations of dogs in neighborhoods correspond to lower robbery and homicide rates, highlighting the deterrent role of dogs in security (Sacks et al., 2023). These patterns raise the possibility that the demand for large, defensive dogs in high-crime areas may inadvertently intensify predation pressure on sloths and other wildlife. Further research is needed to evaluate this potential link between human security practices and wildlife conservation challenges.

### **Causes of admission: Hit by a car**

A total of 68 cases were attributed to car collisions, with 10 (14.8%) involving BV and 58 (85.2%) CH. Vehicular collision prevalence was moderately higher in CH (4.1%) than in BV (1.3%). Mortality rates were high, reaching 71.2%, being similar in both species: CH experienced a slightly higher rate (71.9%) than BV (66.7%). Release rates favored BV (33.3%) over CH (21.1%). Seasonal patterns revealed peaks in July and December for both species, indicating increased vulnerability during these months (Fig. 10a, 10b, 11a, 11b).

The distinct ecological behaviors of *Bradypus* and *Choloepus* influence their rates of vehicular collisions. The first one, with lower mobility and prolonged tree-dwelling, contrasts with the more mobile and nocturnal *Choloepus*, which frequently changes locations (Chiarello 2008; Sunquist & Montgomery 1973). These behavioral traits likely contribute to the higher incidence of electrocution and vehicle collisions in *Choloepus* (de Andrade, 2020). Additionally, habitat destruction, fragmentation, and species-specific activity patterns are key factors driving traumatic cases in urbanized areas. A study in Brazil found a higher density of rescue points in forested regions with high human disturbance (de Andrade, 2020).

We wondered if our 68 cases over 10 years are underestimated, and a larger impact exists from cars on sloths. To test this hypothesis and also check the species-specific differences regarding car collisions, we compared our findings with data from the project *Fauna Atropellada en Carreteras de Costa Rica* (Wildlife Roadkill from Costa Rican Roads), hosted on iNaturalist, a citizen science platform. Public records from this project show that over 10 years until 2025, 1,366 road-killed mammals were documented, covering 61 species. Among sloths, CH accounted for 41 observations, while BV had only 4. These results reinforce the hypothesis that CH is more frequently hit by vehicles than BV, possibly due to differences in habitat use and locomotor behavior. Additionally, these data suggest a potential underestimation of roadkill cases in WRC admissions and highlight the need for further research into the significance of vehicle collisions as a cause of mortality for both species (iNaturalist, 2025).

When comparing our admission data represented in Figure 18 with iNaturalist records of sloth roadkills, clear spatial overlaps and differences emerge. The iNaturalist dataset highlights Route 32 in the Caribbean lowlands (Limón–Guápiles–Siquirres corridor), Route 36 in the South Caribbean (Cahuita–Puerto Viejo–Manzanillo), Route 34 along the Central and Southern Pacific coast, and a notable cluster in the area south of the Osa Peninsula toward the Panama border (Southern Pacific Coast / Zona Sur) as major hotspots for collisions. Additional clusters are evident around the Arenal–La Fortuna region and along peri-urban roads around San José. In contrast, our admissions data identify the Central and Southern Pacific coast and the South Caribbean as the primary hotspots for collision-related rescues. This overlap confirms the risk along high-speed coastal routes but also reveals regional mismatches. The most pronounced discrepancies occur in the Route 32 area and the San José–Arenal–La Fortuna region, where iNaturalist reports show high roadkill densities, but admissions remain low, likely reflecting gaps in rescue coverage and response capacity.

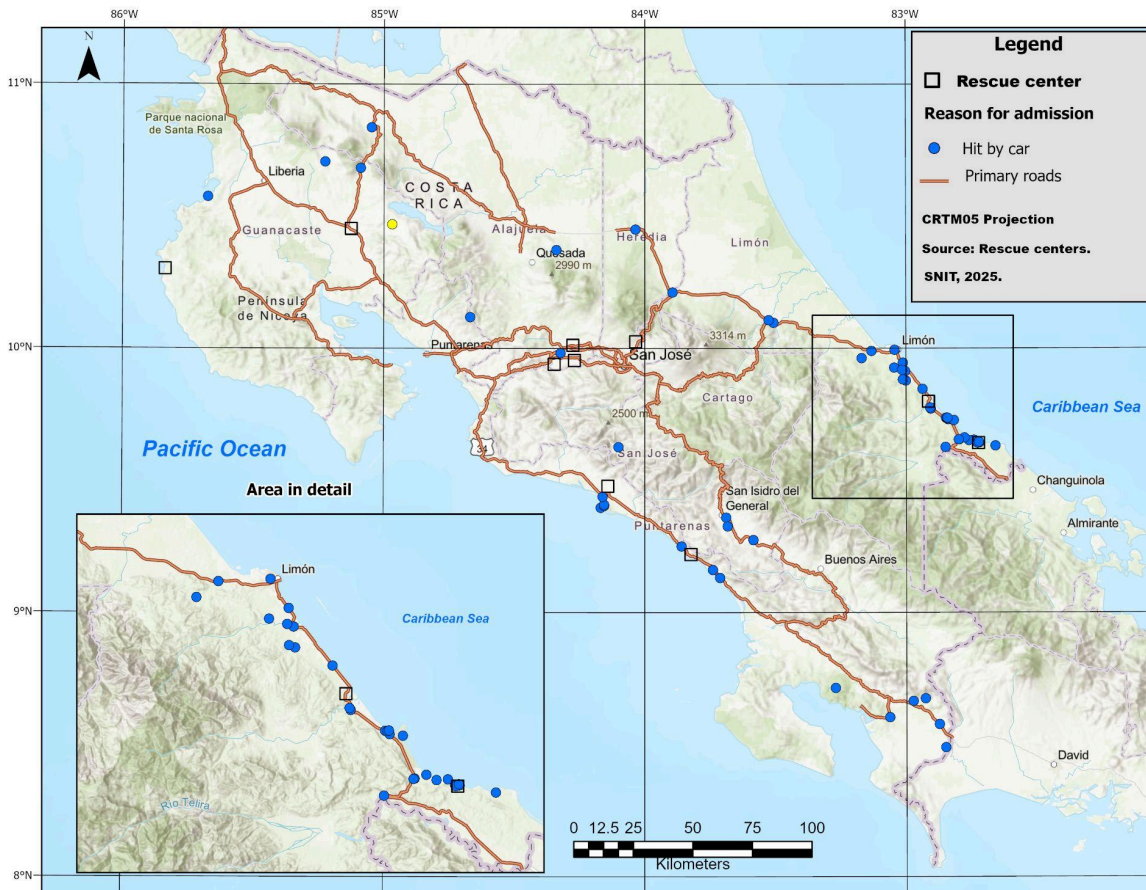


Fig 18. Geographic distribution of sloth-hit-by-car cases.

Villalobos-Hoffman et al. (2022) found that wildlife crossings along Route 34 reduced mammalian roadkill, including arboreal species such as sloths. Their study highlights how limited canopy connectivity near roads increases collision risk, which may explain why *C. hoffmanni*, a more mobile species that frequently changes trees, is recorded more often as roadkill than the more sedentary *B. variegatus*. Similar patterns have been reported globally, where species mobility, road density, and traffic volume are key drivers of wildlife–vehicle collisions, and where roadkill data are often underreported (van der Ree, Smith, & Grilo, 2020). These results reinforce the need for expanded mitigation measures, including additional canopy bridges, underpasses, and systematic hotspot monitoring to reduce risks for sloths and other arboreal mammals.

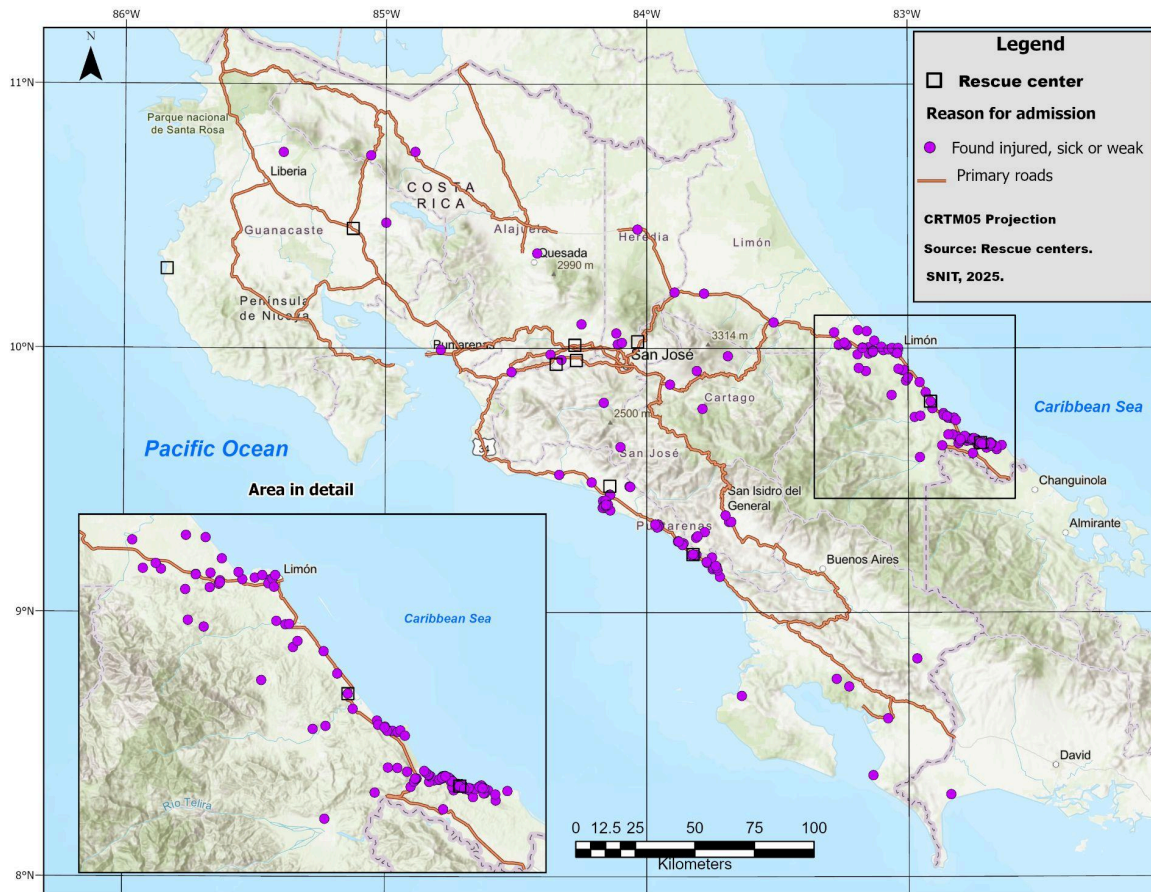
Surviving a vehicular collision poses significant challenges, highlighting the critical need for road safety, habitat conservation, and public awareness strategies. These measures are essential to reduce incidents and enhance the chances of sloth survival, particularly during holidays when the likelihood of such incidents seems to increase.

#### **Causes of admission: Found injured, sick, or weak**

This category includes animals for which the exact cause of admission could not be determined, but that were found unwell, injured, or weak. A total of 372 individuals were admitted under this category: 60.2% corresponded to *C. hoffmanni* (n = 224) and 39.8% to *B. variegatus* (n = 148). Both species showed similar proportions, making this the sixth most frequent cause of admission overall (Fig. 10b). The overall mortality rate for this category was 62.1%, with CH at 63.1% and BV at 60.7%. Release rates were 29.3% for CH and 36.6% for BV.

Seasonal trends indicate peaks in December, February, and August, which may be linked to increased tourism and human activity during these months (Fig 11b). These factors could not only increase the likelihood of sloths being negatively affected but also make them more likely to be found and reported.

This is a broad, non-specific category where no definitive cause was confirmed. It likely includes both naturally occurring diseases and human-related factors that were not explicitly identified. Anthropogenic disturbances in forested habitats are known to increase disease prevalence and susceptibility in arboreal mammals, including sloths (Santos et al., 2023b). The geographic distribution of these cases did not reveal distinct hotspots, largely mirroring the overall spatial pattern observed for all admission causes (Fig. 19).



**Fig. 19.** Geographic distribution of injured, sick, or weak sloth admissions to wildlife rescue centers during the period 2012-2022.

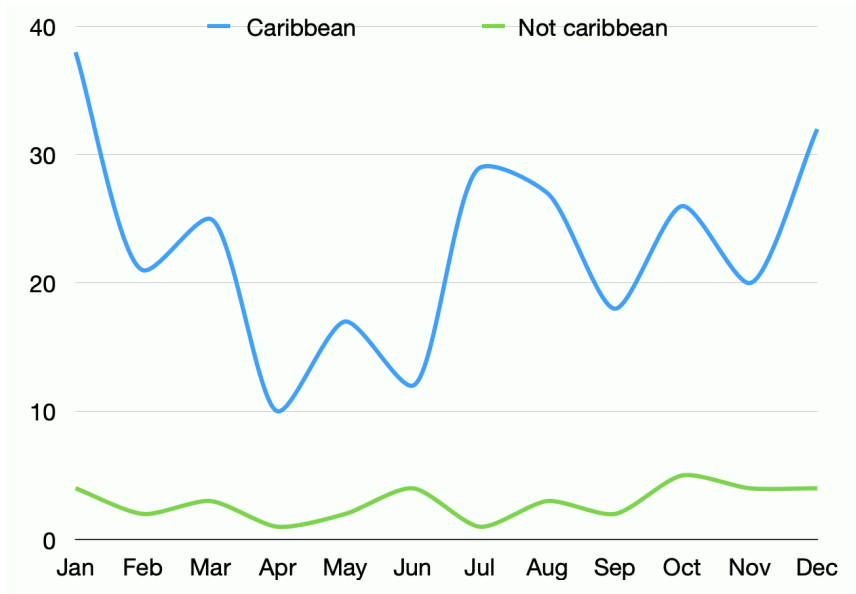
### Causes of admission: Fall from Tree

Falls were the third most common cause of admission, with 310 cases recorded (CH: 159, 51.3%; BV: 151, 48.7%). As a proportion of total admissions, BV was more frequently admitted for falls than CH (BV: 20.3%, CH: 11.1%) (Fig. 10b). Mortality rates were similar between species (CH: 55.4%, BV: 58.3%) (Fig. 10a).

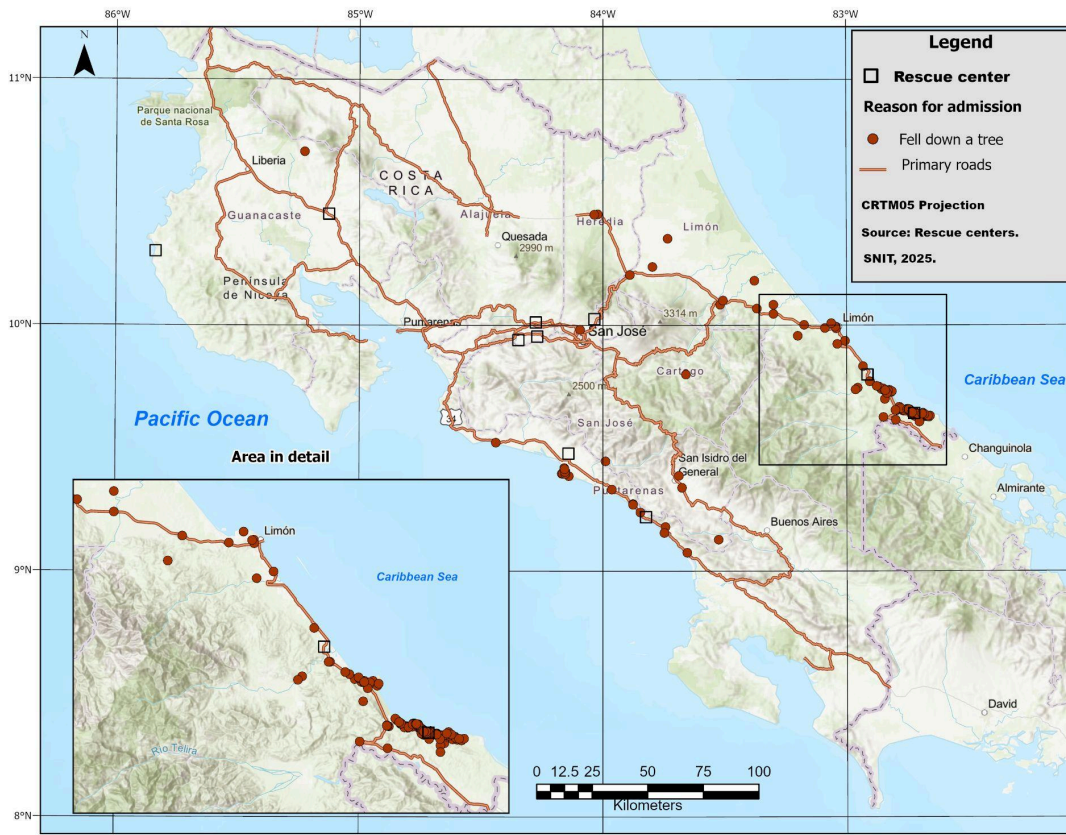
Although falling from trees is natural, the consequences are more severe in human-modified landscapes. Hard ground surfaces, loss of understory vegetation, and reduced canopy connectivity increase the likelihood of serious or fatal injuries, emphasizing the impact of habitat alteration. Spatial analysis of the map indicates that fall-related admissions are concentrated in the Central Pacific and Central Caribbean regions. These hotspots are located near WRCs, where reporting and rescue capacity are higher, and correspond to forested landscapes that are

increasingly fragmented by urban expansion, and tourism development. The overlap of suitable sloth habitat with expanding human activity likely increases both the risk of falls and the likelihood of animals being detected and admitted to rescue centers.

The higher proportion of BV cases could reflect behavioral or anatomical differences, though further research is needed. Seasonality analyses show peaks in January, July, August, and December (Fig. 11a, 11b). Data from Caribbean rescue centers indicated fewer cases in April–June, September, and November, suggesting rainfall patterns may influence falls. In other regions, admissions were more evenly distributed but based on smaller sample sizes, likely reflecting both ecological and reporting differences (Fig 20).



**Fig. 20.** Seasonal distribution of sloth falls by region during the period 2012-2022.



**Fig 21.** Geographical distribution of sloth falls during the period 2012-2022.

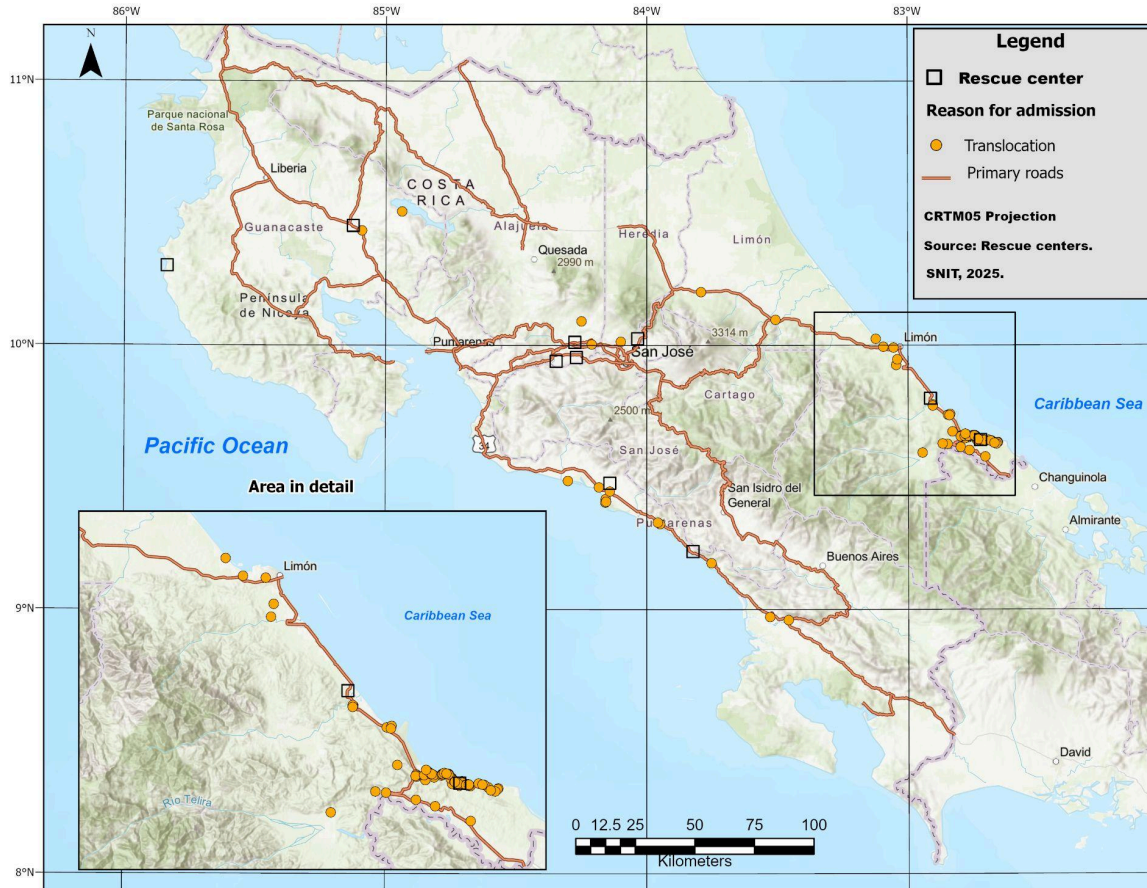
### Causes of admission: Translocations

Translocation refers to the capture and immediate release of healthy animals found in unsuitable or hazardous environments, such as urban areas, gardens, or locations posing imminent risk. A total of 190 sloths were translocated, with BV significantly more represented than CH (Fig. 10a), accounting for 111 cases (14.9%) compared to 79 cases (5.6%) for CH.

The reasons for this species difference are not fully understood, but may be related to behavioral tendencies of BV. This species may be more likely to enter human-modified landscapes, and its more diurnal activity patterns could make it more visible and frequently reported. Further research is required to clarify these trends. Mortality during translocation was rare, with six deaths recorded (four CH and two BV) across three rescue centers. Overall, survival outcomes were favorable, with 184 individuals (96.8%) successfully released.

The geographic distribution of translocation cases shows a clear concentration near WRCs and in urban or peri-urban zones, particularly along coastal regions that remain highly forested. These

areas represent a strong interface between suitable sloth habitat and expanding human activity, where animals are more likely to enter gardens, roadsides, or built environments and subsequently be reported. The proximity to WRCs increases the likelihood of these cases being detected, managed, and recorded, which may partly explain the observed spatial clustering (Fig. 22).



**Fig 21.** Geographical distribution of sloth translocations during the period 2012-2022.

### **Causes of admission: Confiscation and illegal pet trade**

In our dataset, only 15 admissions (0.7%) were linked to confiscations or illegal pet keeping, the majority being *C. hoffmanni* (n = 13) with only two *B. variegatus*. Mortality was high, with five individuals dying shortly after arrival (33.3%; four CH and one BV). Only two BV were recorded, one of which was a juvenile that died soon after confiscation. Some of these cases were confiscated directly by police authorities and subsequently transferred to wildlife rescue centers (Fig 10a, 10b).

Although rare in our records, these numbers almost certainly underestimate the true extent of illegal sloth possession in Costa Rica. National legislation explicitly prohibits the ownership and trade of native wildlife, making private possession illicit and subject to confiscation (Art. 14.d; Art. 18). However, enforcement actions are dispersed across agencies and not systematically integrated into WRC records. Public awareness campaigns, such as the #StopAnimalSelfies initiative launched in Costa Rica, highlight that sloths remain at risk of being illegally handled or kept for tourism and personal use, reinforcing the concern that our data do not capture the full scope of the problem.

Regional evidence further supports that the trade in sloths as pets or tourist attractions is more widespread than our data suggest. In Colombia, Peru, and Brazil, *B. variegatus* and *C. hoffmanni* are frequently captured for sale or used as photo props in tourist areas, with high prevalence of juvenile involvement and associated mortality (Moreno-Salazar et al., 2021; Peck, 2011; Nogueira & Pessôa, 2014; van der Meer, 2014). CITES reports from Panama have also noted confiscations of sloths destined for the pet trade (CITES, 2020). Together, these findings demonstrate that sloth trafficking is a persistent issue across Central and South America and suggest that Costa Rica is unlikely to be exempt.

Given this context, our finding that only 0.7% of admissions were related to confiscations likely reflects detection and reporting biases rather than the true rarity of the practice in Costa Rica. Future research should combine WRC records with enforcement data from the Environmental Ministry (SINAC-MINAE) and police confiscations to more accurately estimate the scale of sloth trafficking and assess its conservation impact.

### **Causes of admission: Other causes**

Several additional causes of admission were recorded, though each represented a relatively small proportion of cases. Intraspecific aggression was reported in nine individuals, eight of whom were CH. Mortality in this group was high, with 50% individuals dying as a result of conspecific injuries.

A few sloths were categorized as “came back weak”, referring to animals previously released that were later recaptured in poor condition. This highlights the challenges of post-release survival monitoring and the importance of long-term follow-up in rehabilitation programs.

Hunting or direct human aggression was rarely reported, with only five cases, all of them CH, and one resulting in death. Although uncommon in our dataset, such incidents may be underreported, given that intentional harm to sloths is seldom documented in official records.

Births at rescue centers were documented 15 times, most involving CH (n = 13) and only two BV. Both BV neonates died shortly after birth, while CH had a comparatively high survival rate

of 84%. These cases emphasize the capacity of pregnant females to carry to term in captivity, but also the greater difficulty of rearing BV neonates successfully.

Finally, an “Other” category included 30 individuals whose causes of admission did not fit any of the defined groups. This residual category reflects the heterogeneity of rescue admissions and the complexity of assigning definitive causes in some cases.

## Conclusions

This study analyzed 2,247 sloth admissions recorded by 10 WRCs in Costa Rica between 2012 and 2022. It represents the first large-scale, nationwide analysis compiling admission records and georeferenced information on the diverse causes affecting sloth health and driving their entry into these centers.

Sloth admissions increased annually, except in 2020, when numbers declined by 5.6% maybe due to the impacts of COVID-19 on tourism and mobility. From 2018 to 2022, the average annual growth rate reached 8.7%. This upward trend reflects intensified human pressures such as settlement expansion, infrastructure development, and tourism in unprotected forested areas, rather than an actual increase in sloth populations. Admissions occurred year-round but consistently peaked in December–January and July–August, slightly earlier for CH than BV, in alignment with reproductive cycles and peak tourism periods that increase human–sloth encounters.

Two-toed sloths were admitted almost twice as often as three-toed sloths. While overall survival rates were identical for both species (43.9%), release outcomes differed: BV achieved higher release success (40.8%) compared to CH (30.3%). Of all admitted sloths, 9.4% remained in captivity, with CH disproportionately represented (188 CH vs. 19 BV). Most BV were still in rehabilitation, with few permanent residents, reflecting the greater challenges of maintaining this species long-term.

Georeferenced comparisons with citizen science records showed that sloths in national parks are less likely to require rescue, while those in human-dominated landscapes face higher risks. Regions such as the central and northern Caribbean, where dense sloth populations occur outside protected areas but rescues remain scarce, highlight the need for expanded rescue coverage and stronger community outreach. Distribution patterns were also uneven nationwide: over 60% of rescues occurred in the South Caribbean, with further concentrations in the central region and the central Pacific coast. CH was widespread but scarce in the Nicoya Peninsula and above 2,400 m. In contrast, BV were even more restricted, confined mainly to coastal lowlands and absent from the Nicoya and northern central regions. Rescue altitudes revealed species-specific patterns, with BV rescued almost exclusively below 100 m, while CH occurred across a broader range, including over 60 rescues above 600 m and up to 2,400 m.

The results support the hypothesis that BV is more fragile in captivity and has lower survival prospects than CH. On average, BV died sooner in care (28 vs. 42 days) and showed markedly higher orphan mortality (71.7% vs. 57.3%). Orphans represented nearly a third of admissions (29.1%) and had low overall survival (38.4%), with CH remaining in care almost four times longer than BV, reflecting their extended dependency period. Together, these findings confirm that *Bradypus* are more difficult to raise successfully in captivity, while *Choloepus* have higher rehabilitation and release potential.

Among anthropogenic threats, electrocution emerged as the leading cause (290 cases, 12.9%), disproportionately affecting CH (17.6% of admissions vs. 5.2% for BV). Mortality was high in both species (63.1%), particularly in BV (74.4%). Data from the Costa Rican Electricity Company (ICE) reported 619 additional cases between 2019 and 2023—2.5 times higher than WRC records—highlighting severe underreporting. Dog attacks were the second major cause (219 cases, 10.1%), with high mortality (68.2%) and particularly frequent in the central and the South Caribbean. Vehicle collisions, though less frequent (70 cases, 3.1%), had the highest mortality (71.4%), disproportionately affecting CH (85.2% of cases). Spatial analysis identified hotspots along Routes 32, 34, and 36 in Arenal–La Fortuna, as well as peri-urban roads near San José, the capital of the country. These overlapped with iNaturalist reports but revealed mismatches in these regions, where roadkill reports were high but rescues were few. Falls, the third most common cause overall (310 cases, 13.9%), were more frequent in BV (20.3% vs. 11.1% for CH) and linked to deforestation and canopy fragmentation.

Other causes included translocations (190 cases, 8.8%), which disproportionately affected BV (14.9% vs. 5.6% for CH), and confiscations of illegal pets (15 cases, 0.7%), mostly affecting CH. These numbers likely underestimate true prevalence due to limited reporting.

Finally, logistical patterns revealed that coastal centers, often located in tourism-oriented regions, admitted sloths from shorter distances (typically <30 km) through local rescues. In contrast, inland centers reported longer average distances, often exceeding 100 km, reflecting their reliance on external institutions such as firefighters or SINAC for transport.

This study identifies electrocutions, dog attacks, and vehicle collisions as the most pressing anthropogenic threats to sloth conservation in Costa Rica, and highlights the need for continuing to monitor the real status of wildlife. While some mitigation measures are already being implemented, such as canopy bridges or power line insulation, prioritizing efforts in the most affected areas and expanding rescue coverage in underrepresented regions (e.g., Caribbean and Central and Southern Pacific) are critical steps to reduce mismatches between threats and responses and strengthen long-term conservation outcomes.

## Final perspective

This study represents the first integrated, multi-rescue center analysis of sloth admissions in Costa Rica. It should serve as a basis for future collaborations with universities and governmental institutions to build shared datasets and develop evidence-based mitigation measures for wildlife conservation.

The results underscore that sloth conservation in Costa Rica cannot rely solely on rehabilitation. Adequate long-term protection requires structural prevention through infrastructure planning, habitat connectivity, and multidisciplinary, community-based actions to reduce the root causes of rescue admissions.

Wildlife rescue centers play a critical role in this process, not only by responding to rescues but also by serving as hubs of knowledge and action. If organized collaboratively to share information and work with national institutions, these centers can provide a broad, unified perspective that strengthens research and magnifies conservation impact across species. By combining accurate rescue data with external datasets (e.g., ICE, iNaturalist), this study outlines a framework for evidence-based interventions that can significantly enhance sloth welfare and population viability in a rapidly changing landscape.

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