ACTA
AMAZONICA | http://dx.doi.org/10.1590/1809-4392202404053

BIODIVERSITY AND CONSERVATION | SHORT COMMUNICATION

Extreme drought and heat lead to alarming mortality of Amazon fauna

Aretha F. GUIMARAES[1,3]*, Juliana SCHIETTI[1,2], Luciano C.A. QUERIDO[1], Jesus NUNES[1], Pedro SANTOS[2], Diogo LAGROTERIA[4], Marcelo GORDO[2]

1 Instituto Nacional de Pesquisas da Amazônia, 69067-375, Manaus, AM, Brazil

2 Universidade Federal do Amazonas, 69067-005, Manaus, AM, Brazil

3 Centro de Conhecimento em Biodiversidade, 31270-901, Belo Horizonte, MG, Brazil

4 Centro Nacional de Pesquisa e Conservação da Biodiversidade Amazonica, 69077-000, Manaus, AM, Brazil

* Corresponding author: areguimaraes@gmail.com

ABSTRACT

The ongoing destruction of the Amazon Forest in Brazil is causing increasing distress to its fauna, leading to alarming mortality among terrestrial and aquatic animals. An El Niño year, 2023 brought extreme drought with record-breaking high temperatures. This, combined with massive amounts of smoke from the many forest fires going on in the biome lead to extremely poor air quality in the Amazon. In this article, we address this issue by providing fieldwork information on the consequences of that extreme drought. We found 19 dead animals (mostly mammals) from October to December 2023, in 16 permanent plots and trails in an urban forest fragment. This is the first time, to our knowledge, that such high mortality rates have been registered in the area. The mortality of terrestrial animals is likely to increase not only as a consequence of extreme droughts, but also due to the combined effects of high temperatures and poor air quality, with severe consequences for fragmented areas.

KEYWORDS: El Niño 2023, urban forest, vertebrates, heat-induced mortality, thermal stress, smoke fog

Seca extrema e onda de calor levam à alarmante mortalidade da fauna Amazônica

RESUMO

A destruição em andamento da Floresta Amazônica no Brasil está causando enorme estresse na fauna, levando a alarmantes taxas de mortalidade entre os animais terrestres e aquáticos. O ano de 2023 foi um ano de El Niño, com um período estendido de seca no bioma. Combinados, o El Niño e a onda de calor no bioma levaram a recordes históricos de temperaturas médias maiores do que o normal e baixo aporte de chuvas, que associados à uma nuvem de fumaça que tomou conta do Estado do Amazonas, culminaram em má qualidade do ar. Neste artigo, nós endereçamos o problema ao prover informações de campo sobre as consequências deste evento de seca extrema. Nós encontramos dezenove animais mortos (a maioria mamíferos) em uma campanha de campo no período de Outubro a Dezembro de 2023, distribuídos em 16 parcelas permanentes e trilhas em um fragmento florestal urbano. Esta é a primeira vez que temos conhecimento de taxas de mortalidades altas registradas para esta área. É provável que as taxas de mortalidade de animais terrestres aumentem nos próximos anos devido ao aumento da severidade das secas e mudanças climáticas induzidas por ação humana, com consequências severas em áreas fragmentadas.

PALAVRAS-CHAVE: El Niño 2023, floresta urbana, vertebrados, mortalidade induzida pelo calor, estresse termal, nuvem de fumaça

The Amazon forest is currently enduring a series of adverse effects as a consequence of global warming. One important ongoing change in the Amazon basin is the increasing extremes of the hydrological cycles, with drier dry (with extended droughts) and wetter wet seasons (Barichivich et al. 2018). These hydro-climatic extremes have affected many groups of organisms in the Amazon basin (Silveira et al. 2016). In Central Amazonia, changes were documented in ant-following birds and predatory fish assemblages, as well as homogenization of palm tree species diversity (Rodrigues-Filho et al. 2024) and many trees suffered increased mortality and decreased growth (Esteban et al. 2021). Further, many of the rivers and other aquatic systems experienced historically low water levels records in 2023, triggering a massive surface water loss (Souza et al. 2024).

The extreme drought of 2023 was a combination of a water deficit and an increased temperature, with a record of 3º above the normal for the period (Espinoza et al. 2024),

CITE AS: Guimaraes, A.F.; Schietti, J.; Querido, L.C.A.; Nunes, J.; Santos, P.; Lagroteria, D.; Gordo, M. 2025. Extreme drought and heat lead to alarming mortality of Amazon fauna. *Acta Amazonica* 55: e55bc24405.

with several heat waves between June and November that may have exacerbated the effects of the drought. Although some of the effects of climate change and extreme events are relatively well described in the literature, especially for trees, the combined effect of drought and heat on animals is poorly documented. In this report, we will add to the current knowledge by describing the effects of the 2023 drought on the terrestrial fauna of a forest fragment in the Amazon.

During the 2023 massive heat wave and extreme drought event associated with the El Niño phenomenon (Costa et al. 2024) an unprecedent mortality of aquatic animals, including the river dolphins *Inia geoffrensis* and *Sotalia fluviatilis* was found (Rodrigues 2023), but without records for how terrestrial animals may have also suffered. Also, fires increased in the region, which may have contributed to the formation of an anomalous smoke cloud.

We provide evidence of the negative consequences of these events in one of the largest, and extremely diverse (Monteiro et al. 2013), urban tropical forest fragments in the world (770 ha – Figure 1b) which is constantly encroached upon by people from the surrounding areas in Manaus, Brazil (Gordo et al. 2013). The forest fragment is part of the Federal University of Amazonas (UFAM) and is surrounded by roads and urban areas (Figure 1b), and the fauna has no refugia due to the lack of consecutiveness between the fragment and other areas. This forest fragment has been monitored since 1998 by a team of researchers from UFAM, and recently became an integral part of the Long-Term Ecological Research project "Anthropogenic Impacts on the Amazon Forest" (PELD-IAFA). It is among the longest long-term research sites in Brazil, and in which many studies have been conducted when dead animals without an apparent cause of death (e.g. road kill, hunting) were seldom encountered.

The Temperature Anomaly (the difference between the monthly temperature in 2023 and the monthly average from the historic period of 2007-2022; Figure 1c) was calculated from hourly measurements from the A101automatic weather station from the Brazilian National Institute of Meteorology (Instituto Nacional de Meteorologia - INMET 2023) in Manaus. Large temperature anomalies (of up to 6 degrees C) were observed between July and October 2023 (Figure 1c).

Nineteen dead terrestrial vertebrates were found in the UFAM forest fragment in October 2023 by our PELD-IAFA research team. We walked on trails and through plots for eight hours daily through the forest fragment during two months, for a sampling effort of approximately 480 walking hours.

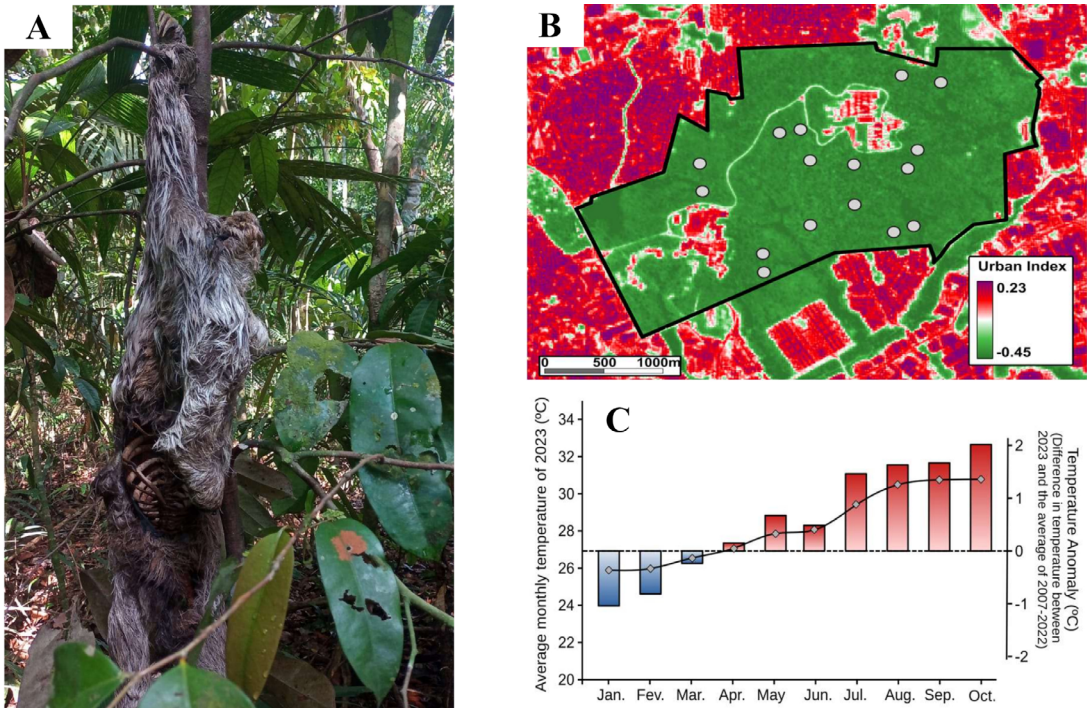

Figure. 1. (A) Example of one of the dead sloths hanging in a tree, found in the Amazon urban fragment. Most of the dead animals were found in the ground, except for this sloth. Credit: Jesus Nunes; **(B)** Urban Index Map from October 2023, showing the difference between forest fragments (green, indicating lower urbanization index scores) and the urbanized matrix (red, with higher urbanization index scores), from Sentinel-2 averaged images. Grey dots indicate the 16 permanent plots inside the fragment. **(C)** Average monthly temperatures in 2023 from January to October (line connecting circles) overlaying Temperature Anomaly (bars). Higher positive values on the Temperature Anomaly (red bars) indicate that the monthly temperature was higher than the historic average, while negative values (blue bars) indicate that the average monthly temperature of 2023 was smaller than the historic average. The Temperature Anomaly was calculated as the difference between the monthly temperature in 2023 and the monthly average from the historic period of 2007-2022.

During this time, we found 19 dead animals dead: 10 sloths (*Bradypus variegatus*, Figure 1a), two snakes (*Boa constrictor*), four agoutis (*Dasyprocta* sp.), two birds (*Pteroglossus* sp.) and one silky anteater (*Cyclopes* sp.). Six animals were found on the trails, and the remaining ten were distributed among the permanent plots. We also found two living sloths in the lower strata of the canopy, and both were emaciated with clear signs of distress. The mortality of sloths in the fragment was estimated in 1.3 dead sloths/ha^{-1}, which is greater than half of the previous recorded live density of 2.2 individuals/ha^{-1} for the same area (Carmo 2002).

Drought and extreme heat likely led to the death of these animals, but because it was not possible to conduct a necropsy due to their advanced decomposition, we offer this as a hypothesis. Sloths typically have a low capacity of thermoregulation compared to other mammals, and their body temperature is influenced by the temperature of their environment (Muramatsu et al. 2022). For example, temperature of the Three-toed Sloth *Bradypus variegatus* varies with ambient temperature, with a low of 29.4 °C when the ambient temperature is 22.5 °C. to a high of 37.8 °C when the ambient temperature is 31.9 °C (Montgomery and Sunquist 1978). Also, because sloths are slow, they may be unable to leave a location when temperatures are too extreme, and this may contribute to their mortality (Pocknee et al. 2023). Extreme high temperature events affect many biological functions, and the consequences varies from increased physiological stress in vertebrates (Murali et al. 2023), brain injuries (Mota-Rojas et al. 2021), changes in cognition and sometimes might lead to massive die-offs (Soravia et al. 2021).

Vertebrates avoid thermal distress by seeking thermal refugia and adjusting their habitat use, and may include entering water (Cunningham et al. 2021). Unfortunately, during the 2023 extreme drought and heat wave, streams in the forest fragments had little to no water available, and so finding water was not an option for the stressed animals. Air quality also became very poor because the heat wave was followed by a cloud of smoke from the surrounding forest fires that may have lead to carbon monoxide poisoning, respiratory distress, and several respiratory or cardiovascular diseases (Sanderfoot et al. 2021), contributing to the overall high mortality.

Drought and heat waves are likely to become worse due to the current global climate crisis (Oliveira et al. 2021), and this is likely to lead to an extinction vortex that will vary by taxa, as well as cause complex and varied biological responses with unpredictable consequences (Rodrigues-Filho et al. 2024). In conclusion, the impacts of the severe droughts and heat waves of 2023 and 2024 may have unforeseen events that must be studied in the Amazonian region. Isolated forest remnants in a non-friendly matrix, such as those found in urban areas similar to the UFAM fragment, are likely to be less resilient, and a multi-taxa approach in future research is critical to understand the how climate changes will manifest in the biological communities exposed to those changes.

ACKNOWLEDGMENTS

We thank: Fundação de Amparo a Pesquisa do Estado do Amazonas (FAPEAM) for the grant #1.02.016301.01102/2023-80 (180/2023) for the Project Análise da Distribuição e Impacto das Mudanças Climáticas em Mamíferos Neotropicais; the Project Biodiversidade e Processos Ecossistêmicos nas Florestas de areia Branca from Projeto Universal do Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, #404233/2023-6). We thank the Programa Institutos Nacionais de Ciência e Tecnologia (INCT da Biodiversidade Amazônica) grant #01.02.016301.02394/2024-50, CNPq (Process #441602/2020-7) and FAPEAM (CHAMADA PÚBLICA Nº 021/2020 - PELD, #01.02.016301.02394/2022-98) for financial support to PELD-IAFA long-term ecological research. We thank the Programa de Pesquisa Ecológica de Longa Duração (PELD) funding to hte fieldwork through CNPq grant #441602/2020-7 and FAPEAM grant #01.02.016301.02394/2022-98 (Edital 021/2020).

REFERENCES

Barichivich, J.; Gloor, E.; Peylin, P.; Brienen, R.J.W.; Schöngart, J.; Espinoza, J.C.; et al. 2018. Recent intensification of Amazon flooding extremes driven by strengthened Walker circulation. *Science Advances* 4: eaat8785.

Carmo, N.D. 2002. *Distribuição, densidade, padrão de atividades, dieta e parasitas de Bradypus tridactylus (Mammalia, Xenarthra) em fragmento florestal na Amazônia Central.* Master's dissertation. Instituto Nacional de Pesquisas da Amazônia/Universidade Federal do Amazonas, Brazil, 62p.

Costa, F.R.C.; Marengo, J.A.; Albernaz, A.L.M.; Cunha, A.P.; Cuvi, N.; Espinoza, J.-C.; et al. 2024. *Policy Brief: Droughts in the Amazon.* Science Panel for Amazon SPA. https://www.theamazonwewant.org/spa_publication/pb-droughts/.

Cunningham, S.J.; Gardner, J.L.; Martin, R.O. 2021. Opportunity costs and the response of birds and mammals to climate warming. *Frontiers in Ecology and the Environment* 19: 300–307.

Espinoza, J.-C.; Jimenez, J.C.; Marengo, J.A.; Schongart, J.; Ronchail, J.; Lavado-Casimiro, W.; et al. 2024. The new record of drought and warmth in the Amazon in 2023 related to regional and global climatic features. *Scientific Reports* 14: 8107.

Esteban, E.J.L.; Castilho, C.V.; Melgaço, K.L.; Costa, F.R.C. 2021. The other side of droughts: wet extremes and topography as buffers of negative drought effects in an Amazonian forest. *New Phytologist* 229: 1995–2006.

Gordo, M.; Calleia, F.O.; Vasconcelos, S.A.; Leite, J.J.F.; Ferrari, S.F. 2013. The Challenges of Survival in a Concrete Jungle: Conservation of the Pied Tamarin (Saguinus bicolor) in the Urban Landscape of Manaus, Brazil. In: Marsh, L.K.; Chapman, C.A. (Eds.), *Primates in Fragments*, Springer New York, New York, NY, p.357–370.

INMET, I.N. de M. 2023. Histórico de Dados Metereológicos - Dados Históricos - Medidas Diárias. (https://portal.inmet.gov.br/dadoshistoricos). Accessed on 03 December 2023.

Monteiro, C.G.; Oliveira, E.C.; Silveira, E.B. 2013. *Fauna e Flora do campus da Universidade Federal do Amazonas*: A maior biodiversidade urbana do Brasil. 289p.

Montgomery, G.G.; Sunquist, M.E. 1978. Habitat selection and use by two-toed and three-toed sloths. In: Montgomery, G.G. (Ed.), *Ecology of Arboreal Folivores*. Smithsonian University Press, Washington, DC, p.329-358.

Mota-Rojas, D.; Titto, C.G.; Orihuela, A.; Martínez-Burnes, J.; Gómez-Prado, J.; Torres-Bernal, F.; et al. 2021. Physiological and Behavioral Mechanisms of Thermoregulation in Mammals. *Animals* 11: 1733.

Murali, G.; Iwamura, T.; Meiri, S.; Roll, U. 2023. Future temperature extremes threaten land vertebrates. *Nature* 615: 461–467.

Muramatsu, D.; Vidal, L.V.; Costa, E.R.; Yoda, K.; Yabe, T.; Gordo, M. 2022. Low-cost thermoregulation of wild sloths revealed by heart rate and temperature loggers. *Journal of Thermal Biology* 110: 103387.

Oliveira, B.F.; Bottino, M.J.; Nobre, P.; Nobre, C.A. 2021. Deforestation and climate change are projected to increase heat stress risk in the Brazilian Amazon. *Communications Earth & Environment* 2: 207.

Pocknee, C.A.; Legge, S.M.; McDonald, J.; Fisher, D.O. 2023. Modeling mammal response to fire based on species' traits. *Conservation Biology* 37: e14062.

Rodrigues, M. 2023. The Amazon's record-setting drought: how bad will it be? *Nature* 623: 675–676.

Rodrigues-Filho, C.A.S.; Costa, F.R.C.; Schietti, J.; Nogueira, A.; Leitão, R.P.; Menger, J.; et al. 2024. Multi-Taxa Responses to Climate Change in the Amazon Forest. *Global Change Biology* 30: e17598.

Sanderfoot, O.V.; Bassing, S.B.; Brusa, J.L.; Emmet, R.L.; Gillman, S.J.; Swift, K.; et al. 2021. A review of the effects of wildfire smoke on the health and behavior of wildlife. *Environmental Research Letters* 16: 123003.

Silveira, J.M.; Louzada, J.; Barlow, J.; Andrade, R.; Mestre, L.; Solar, R.; et al. 2016. A Multi-Taxa Assessment of Biodiversity Change After Single and Recurrent Wildfires in a Brazilian Amazon Forest. *Biotropica* 48: 170–180.

Soravia, C.; Ashton, B.J.; Thornton, A.; Ridley, A.R. 2021. The impacts of heat stress on animal cognition: Implications for adaptation to a changing climate. *WIREs Climate Change* 12: e713.

Souza, C.M.; Marengo, J.; Ferreira, B.; Ribeiro, J.; Schirmbeck, L.W.; Schirmbeck, J.; et al. 2024. Amazon severe drought in 2023 triggered surface water loss. *Environmental Research: Climate* 3: 041002.

RECEIVED: 03/12/2024
ACCEPTED: 10/04/2025
ASSOCIATE EDITOR: Paulo Bobrowiec

DATA AVAILABILITY: The data that support the findings of this study are available, upon reasonable request, from A.F.Guimaraes or J.Schietti, the dataset is not publicly available because the data points are located inside a highly frequented urban fragment inside the city of Manaus and a public available location can endanger future research and can be used as a facilitating point for hunting.