

This file has been cleaned of potential threats.

If you confirm that the file is coming from a trusted source, you can send the following SHA-256 hash value to your admin for the original file.

21a8fcda46e95efe556d1fd11761d48fdcc0f3b9fde934f8ce2edf76c0562514

To view the reconstructed contents, please SCROLL DOWN to next page.



# Brazil's Amazon Oxygen Crisis: How Lives and Health Were Sacrificed During the Peak of COVID-19 to Promote an Agenda with Long-Term Consequences for the Environment, Indigenous Peoples, and Health

Lucas Ferrante<sup>1</sup> · Philip Martin Fearnside<sup>2</sup>

Received: 3 January 2023 / Revised: 23 March 2023 / Accepted: 26 April 2023  
© W. Montague Cobb-NMA Health Institute 2023

## Abstract

In January 2021, oxygen supplies in the Amazon region's largest city were allowed to run out at the peak of the second wave of the COVID-19 epidemic, shocking the world as hospital patients expired for lack of this basic medical resource in Manaus, which during the first COVID-19 wave had become the world's first city to bury its dead in mass graves. Brazil's authorities used this tragedy to further a political agenda that implies enormous environmental and human-rights consequences. Transport of oxygen was used to promote building a road that, together with its planned side roads, would give deforesters access to much of what remains of Brazil's Amazon Forest. Here, we demonstrate that the logistical strategy adopted by the Jair Bolsonaro administration's Ministries of Health and Infrastructure to bring oxygen to Manaus was the worst possible choice, and the foreseeable delay in the arrival of oxygen cost hundreds of lives. Rather than sending trucks to carry oxygen on the nearly impassible Highway BR-319 during the rainy season, the most appropriate transport option was barges on the Madeira River. As oxygen supplies dwindled in Manaus, the families of wealthier COVID-19 victims scrambled to buy the few remaining cylinders at prices out of reach for those in poorer (and often ethnically distinct) economic strata. Ethnic health disparities are aggravated by both the direct consequences of the oxygen crisis and, on the longer term, by the consequences of the highway project that political use of the crisis materially advanced.

**Keywords** Amazon · BR-319 · Economic viability · Highway · Logistics · Madeira River · Oxygen · Pandemics · Public health

Manaus, the largest city in Brazil's Legal Amazon region, experienced a second wave of COVID-19 that began in October 2020 and peaked in January 2021 (Fig. 1), causing the collapse of the city's health and funeral systems [1]. The city was classified as one of the global epicenters of the COVID-19 pandemic [2], mainly because of the high community transmission of SARS-CoV-2 (which causes COVID-19), and Manaus gave rise to the Gamma (P1) variant that was responsible for two-thirds of deaths from COVID-19 in Brazil [1, 2]. Manaus is the capital of the

state of Amazonas, which encompasses roughly one-third of the Legal Amazon region, and the impacts of the Manaus oxygen crisis had a wide geographical reach because all of the state's intensive care units were located in Manaus [3].

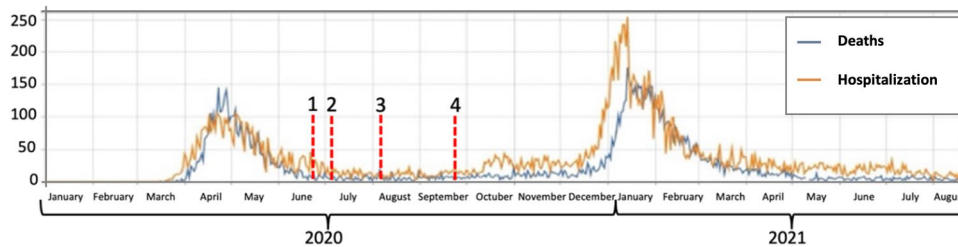
Local politicians (falsely) blamed the second wave of COVID-19 on the emergence of the Gamma (P1) variant [1, 2]. However, studies have shown that the second wave of COVID-19 in Manaus was not generated by the Gamma variant [1, 4], which emerged after the second wave of COVID-19 had already begun: the Gamma variant appeared in Manaus in early November 2020 and became prevalent in January 2021. The second wave was generated by high community transmission, especially due to the 24 September 2020 return to school without vaccination [1, 3, 4].

Politicians also (falsely) blamed the Manaus oxygen crisis on the lack of reconstruction of Highway BR-319 [2], a highway that was built in 1972–1973, abandoned in 1988, and “maintained” since 2015, but not “reconstructed” as a new highway on the same route connecting Manaus to

✉ Lucas Ferrante  
lucasferrante@hotmail.com

<sup>1</sup> Federal University of Amazonas (UFAM), Manaus, Amazonas, Brazil

<sup>2</sup> Department of Environmental Dynamics, National Institute for Research in Amazonia (INPA), Manaus, Amazonas, Brazil



**Fig. 1** Overview of the first and second waves of COVID-19 in Manaus, state of Amazonas. (1) The first warning of the risk of second wave and the need to maintain precautions was given in a technical note requested by the MP-AM. (2) Warning in the *Journal*

*Nacional* newscast. (3) Warning via publication in *Nature Medicine*. (4) Warning at the Legislative Assembly of the State of Amazonas (ALEAM)

Brazil's major population centers. Overestimation of the immunity of the population of Manaus through previous contact with SARS-CoV-2 [4], together with the progressive loss of immunity after exposure [1, 5], contributed greatly to the second wave of COVID-19. The excuse for the lack of oxygen as a result of the absence of reconstructing Highway BR-319 is not plausible because a warning that Manaus would experience a second wave had been given more than 6 months in advance through a technical note prepared at the request of the Public Ministry of the State of Amazonas (MP-AM) [6] (Fig. 1). The warning also had wide national coverage, being reported in Brazil's most highly viewed television newscast (*Jornal Nacional*), where it was pointed out that the second wave of COVID-19 would be much more severe than the first wave [7]. Five months before the second wave in Manaus, a third warning from the same group of researchers was published in the journal *Nature Medicine*, with wide media coverage in Brazil [3]. A fourth warning was given on 24 September 2020 in a public hearing held at the Legislative Assembly of the State of Amazonas (ALEAM) [8].

Given that the second wave of COVID-19 in Amazonas caused a general lack of oxygen and medical supplies in the state capital, which resulted in hundreds of deaths [1, 2], the present study aims to evaluate the best logistical route for the transport of oxygen and medical supplies to the state capital, which is located in the central Amazon, optimizing accessibility, costs, and transportation time to better serve the population during a crisis. We also assess the choice of route used for oxygen transport during the second wave of COVID-19.

Until the second wave reached its peak, the health institutions of the federal and Amazonas state governments denied that a second wave would occur in Manaus [9]. During this peak, even the director of the Health Surveillance Foundation of Amazonas died from COVID-19, despite never acknowledging the warnings from researchers [10]. Federal authorities, such as the Minister of Health (Eduardo Pazuello), tried to justify the lack of preparations by claiming that an increase in COVID-19 cases could not be predicted

[11]. This is untrue, as shown by the various warnings from researchers. It is clear that the authorities in Manaus were aware of the risk of a second wave of COVID-19.

After the explosion of cases of COVID-19 and the beginning of the oxygen crisis in Manaus [1, 2], a post was released on the Twitter account of the Ministry of Infrastructure announcing an emergency route along Highway BR-319 to "facilitate" the transport of oxygen to Manaus during the crisis (Fig. 2). However, the Amazonas state government had known since November 2020 that oxygen in Manaus would be insufficient [12]. The then-Minister of Health (Eduardo Pazuello) also learned that there would be a lack of oxygen in Manaus several days before the critical phase of the second wave of COVID-19 [13]. Many people did not have access to oxygen in Manaus for a period of more than a week due to the high prices of the few cylinders that were left in the city, which increased public health disparities in the state of Amazonas in this period, with only the wealthiest classes having access to oxygen in practice.

The logistics for bringing oxygen to Manaus during the second wave of COVID-19 were the joint responsibility of the Ministry of Health (under Eduardo Pazuello) and the Ministry of Infrastructure (under Tarcísio de Freitas). The Ministry of Infrastructure's publicizing Highway BR-319 as the strategic route to bring oxygen to Manaus (Fig. 2) was seen by supporters of President Bolsonaro as an action that would "save lives" and would demonstrate the government's concern during the crisis. However, the convoy of oxygen trucks heading to Manaus under the responsibility of the Ministry of Infrastructure's National Department of Transport Infrastructure (DNIT) got stuck in the mud on Highway BR-319, a route widely known for its quagmires at this time of year (the rainy season) [14].

The Twitter announcement by the Ministry of Infrastructure stated that the land route to take oxygen to Manaus from Porto Velho on Highway BR-319 would take approximately 30 h, while an alternative route by barge from Belém to Manaus would take 6 to 7 days (Fig. 2). However, the alternative route by barge should instead be along the Madeira River, which runs parallel to Highway BR-319 and connects

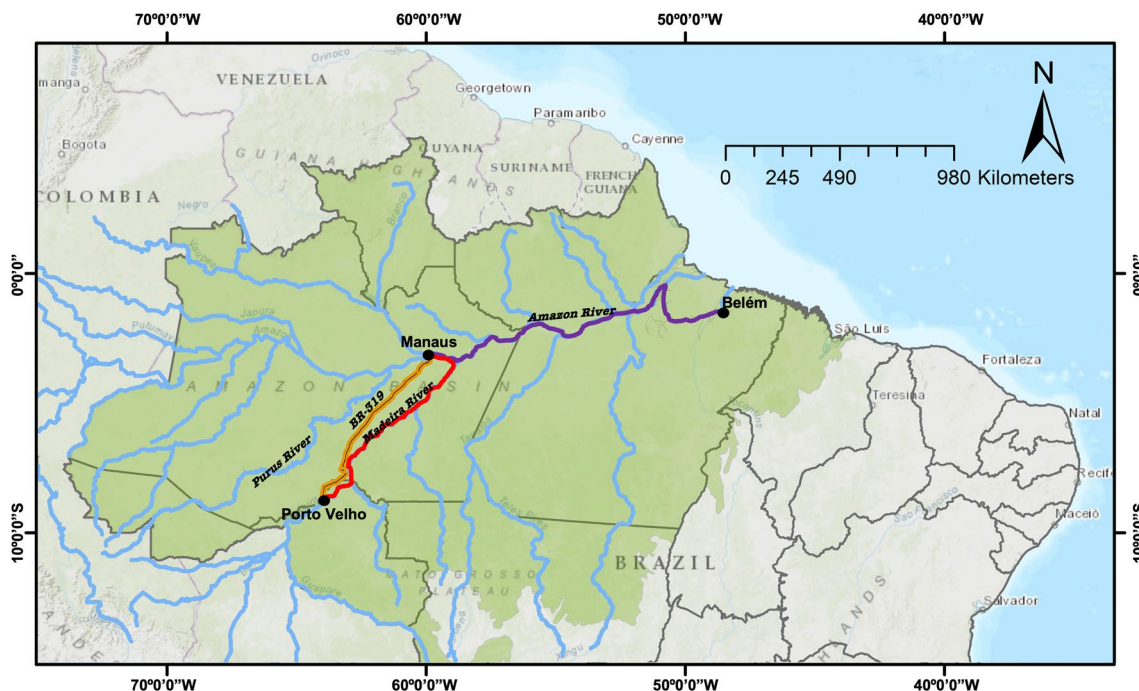
**Fig. 2** Banner from the Ministry of Infrastructure on Twitter announcing the emergency route via BR-319 to facilitate the transport of oxygen to Manaus. Image: Playback



Manaus to Porto Velho, the city from which the oxygen left for Manaus via the highway. The route that the Ministry of Infrastructure claimed to be the alternative to BR-319 was from the more-distant city of Belém and required navigation against the flow of the Amazon River, such that it would take much longer than descending the Madeira River (Fig. 3).

The trip using the route adopted by the Ministries of Infrastructure and Health lasted three times longer than the planned 30 h, and the oxygen convoy finally arrived in Manaus after 96 h (Table 1). Studies on the economic feasibility of transporting cargo to the state of Amazonas have concluded that, even if the highway were reconstructed and

paved, transport via Highway BR-319 would be also much more expensive than river transport [15, 16]. A comparison of oxygen transport by different modes based on travel time, route trafficability, and cost (Table 1) shows that the oxygen crisis in Manaus was exacerbated by the choice of the transport route made by the two ministries. The routes adopted were both the most expensive and the most time-consuming (Table 1). Given the urgent need for oxygen in January 2021, it would have made much more sense to use air transport with aircraft from the Brazilian Air Force (FAB), and it is not justified to relate the oxygen crisis in Manaus to the absence of Highway BR-319.



**Fig. 3** Map of the Brazilian Amazon region with the three routes for transporting oxygen to Manaus. Red line, Madeira River; purple line, Amazon River; orange line, Highway BR-319

**Table 1** Comparison of modes for transporting oxygen to Manaus in the crisis generated by the second wave of COVID-19

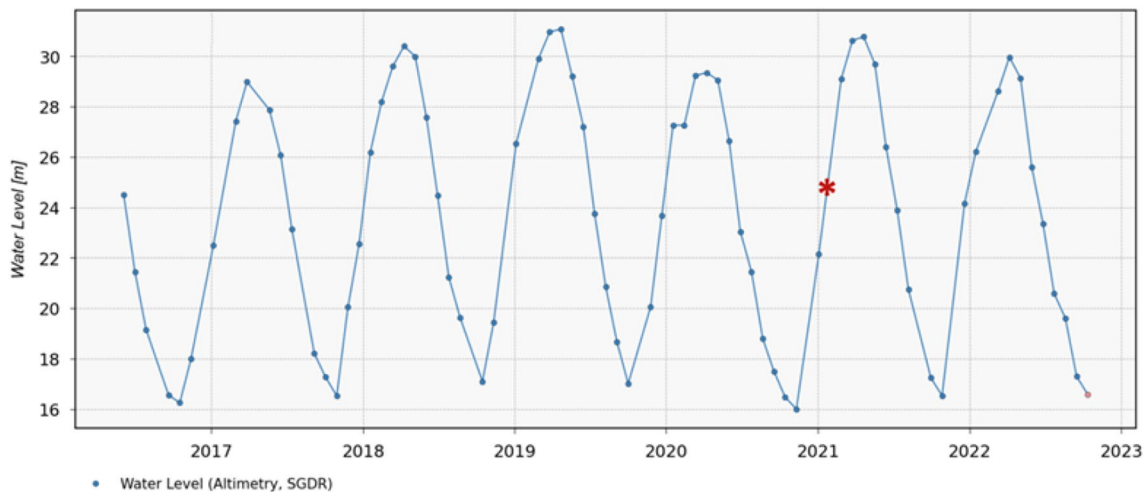
| Mode of transport  | Vehicle  | Actual or estimated travel time                   | Trafficability of the route during the oxygen crisis in Manaus | Shipping cost   |
|--|--|---|--|---|
| Highway BR-319   | 6 trucks   | 4 days (96 h)                                     | Impassable   | Estimated value for shipping only 1.7 million reais** |
| Barges on the Madeira River* (routine trips with shared transport of products) | Conventional pusher tugboat with 350 to 420 HP and a 5.39 reverser | 75 h  | Clear traffic  | 7 to 14 thousand reais                                |
| Barges on the Madeira River* (emergency trip for oxygen only)                  | Conventional pusher tugboat with 350 to 420 HP and a 5.39 reverser | 75 h  | Clear traffic  | 150 thousand reais                                    |
| Barges on the Madeira River* (emergency trip for oxygen only)                  | Power pusher tugboat with 600 to 830 HP and a 5.39 reverser        | 30–52 h depending on draft and sailing conditions | Clear traffic  | 195 thousand reais                                    |

\*Data quoted by shipping companies. The time of 96 h via Highway BR-319 was the duration of the oxygen transfer from Porto Velho to Manaus during the second wave of COVID-19 carried out by the Ministry of Health and by DNIT in the Ministry of Infrastructure. \*\*Total value of transport and oxygen informed by Ministry of Health = 2,767,284.32 reais; Value of one cubic meter of liquid oxygen during the pandemic = 6.50 reais, total by 160 thousand cubic meters = 1.04 million reais.

Under normal navigation conditions, considering the draft of the Madeira River at Porto Velho (Departure) and the draft of the Madeira River at its confluence with the Amazon River (Entrance to the Amazon River bound for Manaus) and a river pilot with solid knowledge of the river, it was estimated that, with the engine working at 1500 to 1800 RPM, the trip would take from 30 to 52 h of travel without interruption. Altimetric surveys using satellite images of water levels in the Madeira River [17, 18] demonstrate that the river was in one of its best periods for trafficability (Fig. 4), unlike Highway BR-319, which had a large number of mud holes due to the large volume of rainfall at that time of year [14].

### The Manaus Oxygen Crisis as a Windfall for Promoting a Highway Project that Increases Health Disparities

Reconstructing Highway BR-319 was a campaign promise of Jair Bolsonaro as a presidential candidate in 2018 (and also in 2022), and, when he took office in 2019, he chose his ministers based on his ideological agenda [19]. President Bolsonaro repeatedly claimed that his Minister of Health at the time of the oxygen crisis (Eduardo Pazuello) was an expert in “logistics,” but Pazuello has



**Fig. 4** Water levels in the Madeira River (Data: [18]). The red asterisk marks the oxygen crisis in Manaus

no training in this area [20]. The president claimed that all his ministers were chosen based on “technical” criteria, including the Minister of Infrastructure (Tarcísio de Freitas) [21]. The then Minister of Health (Eduardo Pazuello) did not provide the oxygen in a timely manner, as concluded by the report of the Parliamentary Commission of Inquiry (CPI) that evaluated the negligence of the federal government in the COVID-19 pandemic [11]. Given that Minister Pazuello summarized his role in the government by stating that the president “commands” and he “obeys” [22], it may be that there was also negligence on the part of President Bolsonaro for the choice of the slower and more expensive means to transport oxygen to Manaus. Negligence lawsuits against then Minister of Health Pazuello (who was a general on active duty in the Army) by the Brazilian Army were placed under 100-year secrecy, such that the expenditure of public funds on this action has not been revealed [23]. Through Brazil’s access-to-information law, we requested access to this confidential information from the Ministry of Health and DNIT-AM (the agency responsible for Highway BR-319 at the time of the oxygen collapse). The Ministry of Health informed us that the oxygen and its transport along the BR-319 highway cost 2,767,284.32 reais. Based on publicly available price quotes for oxygen during the pandemic (R\$6.50/m<sup>3</sup>) [24], the 160,000 cubic meters of liquid oxygen sent to Manaus [25] can be estimated at 1,040,000 reais. This means that the transport via BR-319 cost more than 1.5 million reais more than transport on the Madeira River (Table 1), which was also the fastest mode of transport. It is noteworthy that the vice president of Brazil and head of the Amazon Council (General Hamilton Mourão) had promised that he would eat the beret from his military uniform if Highway BR-319 were not paved before the end of President Bolsonaro’s term in office [26]. The mayor of Manaus (David Almeida) also seized on the oxygen crisis as an opportunity to promote the highway, a project whose priority derives not from any economic rationale but rather from its role in winning votes in Manaus [27].

The operation to drive the trucks transporting oxygen via BR-319, including the use of a bulldozer to tow them through mud holes [14, 27], should not be seen as a heroic strategy or a demonstration of the isolation of the region, but rather as a negligent action with respect to the health needs of the population at that time and an attempt to lobby for a road that rips through the Amazon rainforest and that is unfeasible both economically [15, 16] and environmentally [28–31], in addition to violating the rights of indigenous peoples [30–33]. A federal judge in Brasília (I’talo Fioravanti Sabo Mendes) used the oxygen crisis in Manaus as a legal argument to allow the public hearings in the licensing

process to proceed when COVID-19 prevented the participation of indigenous peoples [34]. This argument is false, as shown by this study. It is necessary to revoke the public hearings held by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) to approve the preliminary license for reconstructing Highway BR-319 because the need for participation of the indigenous peoples impacted by the project was ignored [32].

We would encourage the Federal Public Ministry to consider representations against former Minister Eduardo Pazuello, former Minister Tarcísio de Freitas, and former President Jair Messias Bolsonaro for omission during the oxygen crisis in Manaus at the same time that they used the crisis to promote a campaign promise by President Bolsonaro [31]. Given that a court decision used a false technical basis [34] to justify allowing IBAMA to hold public hearings on the environmental studies for Highway BR-319 in the middle of the pandemic, jeopardizing the future of the more than 18,000 impacted indigenous people [32], it is recommended that the public hearings that have already been held be revoked immediately. In addition, a technical document requested by the Federal Public Ministry from the National Institute for Research in the Amazon pointed out that the environmental studies for the middle section of Highway BR-319 are insufficient, requiring further studies [35]. This adds to the evidence that the public hearings carried out by IBAMA as part of the licensing process did not follow all the legal requirements determined by Brazilian environmental legislation. The presidential administration of Jair Bolsonaro dismantled the environmental licensing process in Brazil [36, 37] and, specifically in the case of Highway BR-319, disregarded court decisions that had determined the need for additional environmental studies and for consultation with indigenous peoples [28].

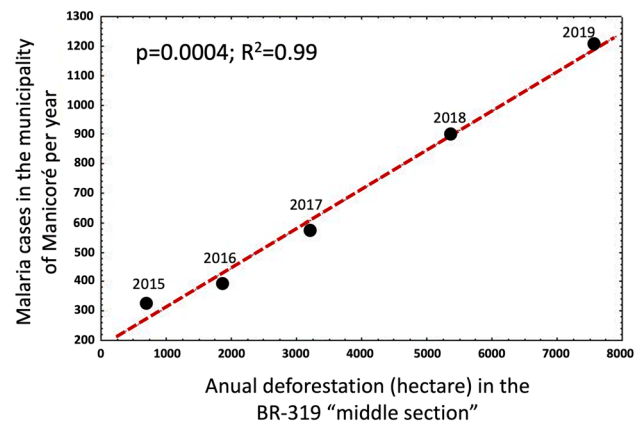
Acceleration of the Highway BR-319 project during the pandemic led to the spread of the coronavirus in indigenous villages near the highway [31]. Indigenous peoples were the group most affected by the COVID-19 pandemic in Brazil [2, 38]. This is because indigenous peoples are part of the risk group for COVID-19 due to genetic factors and the social and economic vulnerabilities of communities [3, 5, 39]. COVID-19 is especially lethal for these peoples, as it mainly affects the elderly people who are responsible for the oral transmission of the group’s traditions. Contamination of an indigenous community by COVID-19 can decimate an entire culture due to the death of elders or *caciques* (heads of communities) [3]. Maintenance of traffic along the Madeira River rather than along Highway BR-319 would help to preserve ethnic groups of traditional peoples in the Amazon, since Highway BR-319 has been found to increase health disparities to the detriment of the most vulnerable ethnic groups.

## Risk of New Pandemics

Appropriate routes for the transport of oxygen and other medical supplies need to be established at this time for the Amazon region because the region is the most susceptible in Brazil to the emergence of a new pandemic [40]. This may occur due to the growing environmental degradation in the region, which leads to zoonotic leaps with the potential to provoke new pandemics [40–42]. Deforestation resulting from reconstructing Highway BR-319 is likely to cause an expansion to the central Amazon of climate anomalies already registered in the “arc of deforestation” [43], which would further degrade the forest and increase the risk of the emergence of a new pandemic in this area.

This adds to the concerns surrounding the extraordinary potential for degradation generated by Highway BR-319 [28–31] and reinforces the importance of the Madeira River as the main route to Manaus. The mayors of several municipalities in the interior of Amazonas have falsely argued that the lack of trafficability on Highway BR-319 increases disparities in public health in the state, and politicians in Manaus have claimed that the highway is necessary to supply fuel and goods and to transport people who need to travel for medical care [44]. However, the potential of BR-319 to increase health disparities is also shown by the relation of this highway to malaria in the municipalities (counties) it bisects, such as Manicoré, where there is a strong relationship between environmental degradation (increased deforestation) and the increase in malaria in the municipality (Fig. 5). Transport of fuel and other goods is more feasible by means of barges on the Madeira River than by BR-319 [15, 16 and Table 1]. Transport of patients to hospitals would, indeed, be facilitated by the highway, but this in no way justifies the reconstruction project because improving the health of the population in the interior of Amazonia would be much better served by investing the funds intended for the highway in building and staffing health clinics throughout the interior, rather than benefiting the lucky few along the highway route at a high cost.

Warnings like the present one of the zoonotic jumps with risk of a new pandemics from environmental degradation and deforestation are often unheeded, as the case for warnings of the COVID-19 pandemic a year before it emerged, with the identification of coronaviruses in bats in the Wuhan region of China [45]. Because the Amazon is one of the world’s largest reservoirs of zoonoses [42], a new global public health crisis arising in the Amazon would be potentially even more significant than the one that occurred in China. The increase in endemic diseases due to environmental degradation in the Highway BR-319 area is a bioindicator of an imminent zoonotic risk (Fig. 5). These indicators must be considered by the environment agencies that will decide



**Fig. 5** Annual numbers of positive cases of malaria in the municipality of Manicoré (which is cut by the middle section of Highway BR-319) in relation to the annual deforestation of the section. The year 2015 marks the beginning of maintenance and trafficability of Highway BR-319, after its abandonment. Data on the number of malaria cases were obtained from the Center for Endemic Diseases of Manicoré (*Centro de Endemias de Manicoré*). Annual deforestation data for the middle section of Highway BR-319 were extracted from the Deforestation Monitoring Project in the Brazilian Amazon (PRODES) of Brazil’s National Institute for Space Research (INPE)

on licensing the BR-319 reconstruction project. The environmental risk to public health is one of the factors contributing to the environmental unfeasibility of the enterprise.

Ignoring epidemiological alerts led to the catastrophic second wave of COVID-19 in January 2021 (Fig. 1), and the zoonotic risks of reconstructing Highway BR-319 are great given the large zoonotic stock present in the Amazon rainforest [40, 42]. Ignoring scientific studies has cost lives in Brazil [46], and decision-makers cannot escape accountability when ignoring the warnings of scientists results in catastrophes. Highway BR-319 has been shown to be unfeasible both economically ([15, 16] and Fig. 2) and environmentally [29–31], and it is also damaging from a public health perspective.

## Conclusion

We conclude that the Manaus oxygen crisis was used to promote the proposed reconstruction of Highway BR-319, a project with tremendous environmental and human consequences that include health impacts on indigenous peoples and increased risk of new pandemics. The political use of the oxygen crisis increased public health disparities in Brazil’s state of Amazonas, especially by impacting the health of indigenous peoples—the most vulnerable ethnic group. The choice of BR-319 as the route to bring oxygen to Manaus cost hundreds of lives and aggravated health disparities in

Amazonia's largest city. It was clear at the time that the best route for transporting oxygen and other medical supplies to Manaus was not BR-319, but rather by waterway on the Madeira River. Our results also indicate that reconstructing Highway BR-319 would increase disparities in public health and that just the maintenance project for the current highway has led to an increased number of cases of endemic diseases, such as malaria. Reconstructing BR-319 would also increase the risk of zoonotic jumps that could give rise to new pandemics. This adds to the many impacts suggesting that Brazil's environmental agencies would be well advised to stop the proposed reconstruction project.

**Author Contribution** LF conceived of the idea. LF collected data. LF and PMF wrote and revised the manuscript.

**Funding** This study was supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), and Fundação de Amparo à Pesquisa do Estado do Amazonas (FAPEAM).

**Data Availability** Links in the manuscript.

**Code Availability** Not applicable.

## Declarations

**Ethics Approval** Not applicable

**Consent to Participate** Not applicable

**Consent for Publication** Not applicable

**Conflict of Interest** The authors declare no competing interests.

## References

- Ferrante L, et al. Dynamics of COVID-19 in Amazonia: a history of government denialism and the risk of a third wave. *Prev Med Rep.* 2022;26:01752. <https://doi.org/10.1016/j.pmedr.2022.101752>.
- Ferrante L, et al. How Brazil's president turned the country into a global epicenter of COVID-19. *J Public Health Policy.* 2021;42:439–51. <https://doi.org/10.1057/s41271-021-00302-0>.
- Ferrante L, et al. Brazil's policies condemn Amazonia to a second wave of COVID-19. *Nat Med.* 2020;26:1315. <https://doi.org/10.1038/s41591-020-1026-x>.
- Ferrante L, et al. Brazil's COVID-19 epicenter in Manaus: how much of the population has already been exposed and are vulnerable to SARS-CoV-2? *J Racial Ethn Health Disparities.* 2021;9:2098–104. <https://doi.org/10.1007/s40615-021-01148-8>.
- Ferrante L, et al. The first case of immunity loss and SARS-CoV-2 reinfection by the same virus lineage in Amazonia. *J Racial Ethn Health Disparities.* 2021;8:821–3. <https://doi.org/10.1007/s40615-021-01084-7>.
- Ferrante L, et al. Nota técnica de avaliação e diretrizes para tomada de decisão frente à pandemia da COVID-19 em Manaus. Manaus: Ministério Público do Estado do Amazonas (MPAM); 2020. <https://www.mpam.mp.br/noticias-portal/slides-noticias/13077-covid-19-mpam-recebe-de-cientistas-nota-tecnica-contraria-a-flexibilizacao-das-restricoes-a-partir-de-1-de-junho#.Y1iU9ezMJ3I>
- Nacional J. Mortalidade por Covid-19 no Amazonas é 4 vezes maior do que a média nacional, diz estudo. *J Nacional.* 2020; <https://globoplay.globo.com/v/8604056/?s=0s>
- ALEAM (Assembleia Legislativa do Estado do Amazonas). Audiência Pública virtual. ALEAM. Manaus; 2020. <https://www.youtube.com/watch?v=KBZQ6BUEDq8>
- Santos I. Amazonas vive segunda onda de Covid-19, mas autoridades negam. *Amazônia Real.* 2020; <https://amazoniareal.com.br/amazonas-vive-segunda-onda-de-covid-19-mas-autoridades-negam-28-10-2020/>
- Carvalho R. Políticos do Amazonas mantêm apoio a Bolsonaro mesmo com colapso na saúde. *Congresso em Foco.* 2021; <https://congressoemfoco.uol.com.br/projeto-bula/reportagem/politicos-do-amazonas-mantem-apoio-a-bolsonaro-mesmo-com-colapso-na-saude/>
- Senado Federal. CPI da Pandemia. 2021. <https://legis.senado.leg.br/comissoes/comissao?codcol=2441>
- Resk F, Carvalho MA. Amazonas sabia desde novembro que oxigênio de hospitais era insuficiente. *UOL.* 2021; <https://noticias.uol.com.br/saude/ultimas-noticias/estado/2021/01/16/amazonas-sabia-desde-novembro-que-oxigenio-de-hospitais-era-insuficiente.htm>
- Reuters. Saúde sabia do risco de falta de oxigênio 6 dias antes do colapso em Manaus. *UOL.* 2021; <https://noticias.uol.com.br/saude/ultimas-noticias/reuters/2021/01/18/saude-sabia-do-risco-de-falta-de-oxigenio-6-dias-antes-do-colapso-em-manaus.htm>
- Jornal Hoje. Comboio com oxigênio para Manaus atola BR-319. *Jornal Hoje.* 2021; <https://globoplay.globo.com/v/9204764/>
- Fleck L. Eficiência Econômica, Riscos e Custos Ambientais da Reconstrução da BR 319. 53 pp. Série Técnica, no. 17. Conservation Strategy Fund (CSF), Lagoa Santa, MG, Brazil. 2009. <https://www.conservation-strategy.org/publication/eficiencia-economica-riscos-e-custos-ambientais-da-reconstrucao-da-rodovia-br-319>
- Teixeira KM. Investigação de Opções de Transporte de Carga Geral em Containeres nas Conexões com a Região Amazônica. In: Universidade de São Paulo, Escola de Engenharia de São Carlos, Doctoral thesis in transport engineering. São Carlos; 2007. p. 235. [https://teses.usp.br/teses/disponiveis/18/%2018137/tde-27112007-110022/publico/KARENINA\\_2007.pdf](https://teses.usp.br/teses/disponiveis/18/%2018137/tde-27112007-110022/publico/KARENINA_2007.pdf).
- Schwatke C, et al. DAHITI - an innovative approach for estimating water level time series over inland waters using multi-mission satellite altimetry. *Hydrol Earth Syst Sci.* 2015;19:4345–64. <https://doi.org/10.5194/hess-19-4345-2015>.
- DAHITI. Madeira, River. Water Level Time Series (Altimetry). 2022. <https://dahiti.dgfi.tum.de/en/13730/water-level-altimetry/>
- Ferrante L, Fearnside PM. Brazil's new president and 'ruralists' threaten Amazonia's environment, traditional peoples and the global climate. *Environ Conserv.* 2019;46:261–3. <https://doi.org/10.1017/S0376892919000213>.
- Congresso em Foco. Eduardo Pazuello não tem formação acadêmica em logística. *Congresso em Foco.* 2021; <https://congressoemfoco.uol.com.br/area/governo/eduardo-pazuello-nao-tem-formacao-academica-em-logistica/>
- Verdélío A. Bolsonaro defende escolha de ministros por critérios técnicos. *Agência Brasil.* 2022. <https://agenciabrasil.ebc.com.br/politica/noticia/2022-08/bolsonaro-defende-escolha-de-ministros-por-criterios-tecnicos>
- Basilio P. 'Um manda, o outro obedece', já disse Pazuello sobre Bolsonaro; veja frases polêmicas do ministro. *G1.* 2021; <https://g1.globo.com/politica/noticia/2021/03/15/um-manda-o-outro-obedece>



- ce-ja-disse-pazuello-sobre-bolsonaro-veja-frases-polemicas-do-ex-ministro.ghtml
23. Gomes PH. Exército diz que agiu conforme a lei ao estabelecer sigilo de 100 anos a processo de Pazuello. G1. 2021; <https://g1.globo.com/politica/noticia/2021/06/08/exercito-atribui-a-lei-sigilo-de-100-anos-em-processo-sobre-ida-de-pazuello-a-ato-com-bolsonaro.ghtml>
  24. Cotação de Oxigênio Líquido – IBG Industria Brasileira de Gases. 2020. <https://hospital-formosa.org.br/wp-content/uploads/2021/03/031-2020-IBG-FORNECIMENTO-OXIGENIO-LIQUIDO.pdf>
  25. Marques P. Comboio com 160 mil m<sup>3</sup> de oxigênio chega com atraso em Manaus devido a condições da BR-319. G1. 2021. <https://g1.globo.com/am/amazonas/noticia/2021/01/24/comboio-com-160-mil-m-de-oxigenio-chega-com-atraso-em-manaus-devido-a-condicoes-da-br-319.ghtml>
  26. Ferrante L, Fearnside PM. Military forces and COVID-19 as smokescreens for Amazon destruction and violation of indigenous rights. *Erde*. 2020;151:258–63. <https://doi.org/10.12854/erde-2020-542>.
  27. Fearnside PM, et al. Brazil's BR-319: politicians capitalize on the Manaus oxygen crisis to promote a disastrous highway (Commentary). *Mongabay*. 2021; <https://news.mongabay.com/2021/02/brazils-br-319-politicians-capitalize-on-the-manaus-oxygen-crisis-to-promote-a-disastrous-highway-commentary/>
  28. Ferrante L, Fearnside PM. Amazon's road to deforestation. *Science*. 2020;369:634. <https://doi.org/10.1126/science.abd6977>.
  29. Andrade M, et al. Brazil's Highway BR-319 demonstrates a crucial lack of environmental governance in Amazonia. *Environ Conserv*. 2021;48:161–4. <https://doi.org/10.1017/S0376892921000084>.
  30. Ferrante L, et al. Brazil's Highway BR-319: The road to the collapse of the Amazon and the violation of indigenous rights. *Erde*. 2021;152:65–70. <https://doi.org/10.12854/erde-2021-552>.
  31. Ferrante L, et al. Land grabbing on Brazil's Highway BR-319 as a spearhead for Amazonian deforestation. *Land Use Policy*. 2021;108:105559. <https://doi.org/10.1016/j.landusepol.2021.105559>.
  32. Ferrante L, et al. Amazonian indigenous peoples are threatened by Brazil's Highway BR-319. *Land Use Policy*. 2020;94:104548. <https://doi.org/10.1016/j.landusepol.2020.104548>.
  33. Ferrante L, Fearnside PM. Brazilian Government violates Indigenous rights: what could induce a change? *Erde*. 2021;152:200–11. <https://doi.org/10.12854/erde-2021-584>.
  34. Mendes IFS. Processo: 1035291-44.2021.4.01.0000 Processo referência: 1022245-88.2021.4.01.3200. Brasília: Tribunal Regional Federal da 1ª Região; 2021. <https://bit.ly/3IWBika>
  35. Magnusson WE. Análise do EIA-RIMA do trecho do meio da rodovia BR-319. Re: Ofício n° 205/2019/9° OFÍCIO/PR/AM (expediente PR/AM-00055261/2019). 2020. <https://bit.ly/3LsA6zV>
  36. Ruaro R, et al. Brazil's doomed environmental licensing. *Science*. 2021;372:1049–50. <https://doi.org/10.1126/science.abj4924>.
  37. Ruaro R, et al. Loosening of environmental licensing threatens Brazilian biodiversity and sustainability. *Erde*. 2022;153:60–4. <https://doi.org/10.12854/erde-2022-614>.
  38. Sansone NMS, et al. Severe acute respiratory syndrome by SARS-CoV-2 infection or other etiologic agents among Brazilian indigenous population: an observational study from the first year of coronavirus disease (COVID)-19 Pandemic. *Lancet Reg Health – Amer*. 2022;8:100177. <https://doi.org/10.1016/j.lana.2021.100177>.
  39. Ferrante L, Fearnside PM. Protect Indigenous peoples from COVID-19. *Science*. 2020;368:251–2. <https://doi.org/10.1126/science.abc0073>.
  40. Winck GR, et al. Socioecological vulnerability and the risk of zoonotic disease emergence in Brazil. *Sci Adv*. 2022;8:eabo5774. <https://doi.org/10.1126/sciadv.abo5774>.
  41. Ferrante L, et al. Brazil's planned exploitation of Amazonian indigenous lands for commercial agriculture increases risk of new pandemics. *Reg Environ Chang*. 2021;21:81. <https://doi.org/10.1007/s10113-021-01819-6>.
  42. Ellwanger JH, et al. Beyond diversity loss and climate change: impacts of Amazon deforestation on infectious diseases and public health. *An Acad Bras Cienc*. 2020;92:e20191375. <https://doi.org/10.1590/0001-3765202020191375>.
  43. Ferrante L, et al. Effects of Amazonian flying rivers on frog biodiversity and populations in the Atlantic Rainforest. *Conserv Biol*. 2023:e14033. <https://doi.org/10.1111/cobi.14033>.
  44. Dia a Dia Notícia. Omar recebe prefeitos do Amazonas para discutir reconstrução de pontes da BR-319 e asfaltamento da BR-174. *Dia a Dia Notícia*. 2023; <https://diaadianoticia.com.br/omar-recebe-prefeitos-do-amazonas-para-discutir-reconstrucao-de-pontes-da-br-319-e-asfaltamento-da-br-174/>
  45. Fan Y, et al. Bat coronaviruses in China. *Viruses*. 2019;11:210. <https://doi.org/10.3390/v11030210>.
  46. Diele-Viegas L, et al. Scientific denialism threatens Brazil. *Science*. 2021;374:948–9. <https://www.science.org/doi/10.1126/science.abm9933>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.