# SUPPLEMENTARY INFORMATION - Mechanistic yellow fever modelling under climate change in Brazil and beyond: Information gaps and future steps

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## Wordclouds of highlighted discussion topics

Participants were asked to add their thoughts on the priority areas of uncertainty, barriers to information access and data gaps for each of the main themes; the results are shown in Figures A1-A5.

## Resources identified through participants

- https://salve.icmbio.gov.br/#/ Sistema de Avaliação do Risco de Extinção da Biodiversidade - SALVE
- http://gal.datasus.gov.br/GALL/index.php?area=01 The Laboratory Environment Management System (GAL). Federal access only.
- https://www.febreamarelabr.com.br/PaginaInicial "The Yellow Fever BR Project was created to monitor and prevent human cases of the Yellow Fever virus through its early detection in samples from non-human primates and mosquitoes in the five Brazilian regions."
- https://www.biodiversidade.ciss.fiocruz.br/

## Data gaps worksheet summaries and notes from the workshop

Worksheet summaries and notes are given in Tables A1-A4.


**Figure A1. Wordcloud responses from participants when asked to highlight priority gaps and uncertainties: Climate**

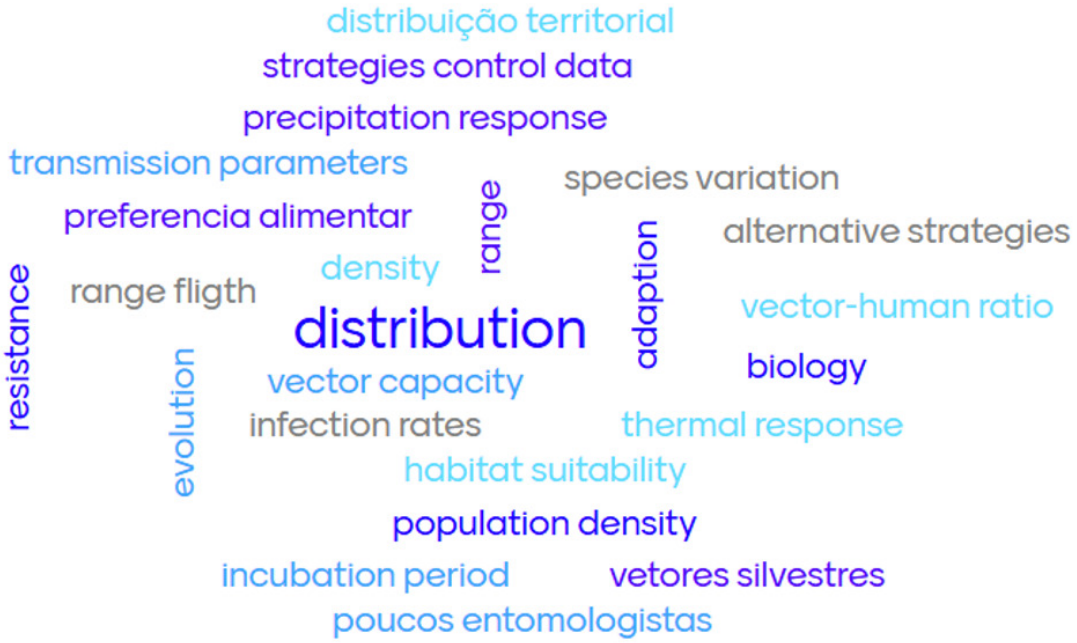


**Figure A2. Wordcloud responses from participants when asked to highlight priority gaps and uncertainties: Vector**


**Figure A3. Wordcloud responses from participants when asked to highlight priority gaps and uncertainties: Non-human primates**


**Figure A4. Wordcloud responses from participants when asked to highlight priority gaps and uncertainties: Virus**

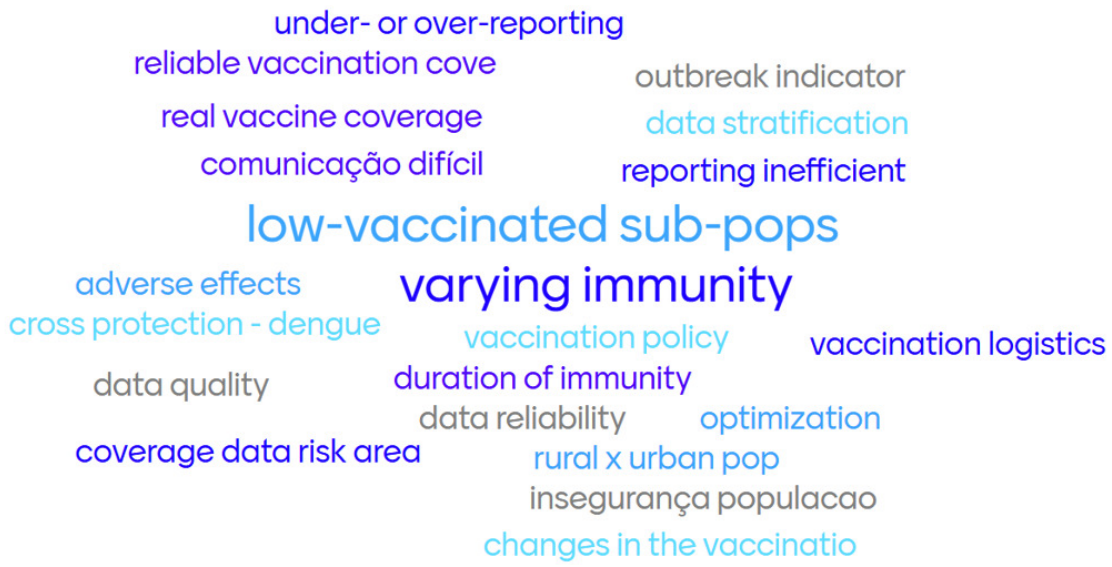


**Figure A5. Wordcloud responses from participants when asked to highlight priority gaps and uncertainties: Vaccination**

| Key Data Gaps | Existence of data | Challenges | Strategy for obtaining | What the data could facilitate |
|---|---|---|---|---|
| Mortality data | The Ministry of Health has the largest database of dead animals, around 50 thousand in historical series, however the data is fragile and most of it does not have gender or species data. ICMBio is evaluating the MS list to refine the genera by species distribution in the territory. SISS-Geo/Fiocruz has more recent, georeferenced and taxonomically validated data with part of the diagnostic results. | Political decisions to integrate systems | Establish working groups with the same objective. Present the demand for the need to integrate the database for non-human primates and other animals to the Inter-ministerial Group for One Health to strengthen agreement between Ministries and institutions | |
| Population data | Systematize information on species that are monitored over long distances (muriquis and golden lion tamarins). Recommendation to use Brazilian data, which is more up-to-date and more appropriate to the species available in the SALVE system | Permission to access sensitive data in the database of ICMBio/CPB | Group cooperation agreement with governmental and non-governmental institutions holding databases. Encourage the use of SISS-Geo for information collection by society and research groups for studies. Expand field research, publish comprehensive databases, identify and intensify surveillance in neighboring areas with positive occurrences | |
| Immunity/ susceptibility of different primate species | Callithrix viral load in the northeast (outbreak in Bahia) is higher. In the south, the viral load decreases with correlation with a different genome. Proposed studies for the red howler monkey and golden lion tamarin in the Action Plan for Endangered Species. | Data collection is resource intensive | Support existing groups to collect these data | |
| Adaptation to other hosts | In São Paulo, after the virus depletes the population of favorable species, the virus disappears. A study carried out by the IEC showed that Callithrix jacchus transmitted the virus to Ae. albopictus and the mosquito to Callithrix | Field work, experimental studies | Support the groups that carry out these studies | |
| Vaccination | Only some species groups are eligible for vaccination - threatened with extinction in monitored groups and in captivity. Studies are underway at CPRJ and BioManguinhos/Fiocruz and with golden lion tamarins. Other studies have established safety of vaccination | | ICMBIO/CPB will monitor vaccination in authorized projects. Animals will be microchipped and information on species/location/animal will be provided to CGARB/MS. | |

**Table A 1. Summary of data gaps discussed in Non-human primates.**

| Key Data Gaps | Existence of data | Challenges | Strategy for obtaining | What the data could facilitate |
|---|---|---|---|---|
| Role of humans in maintaining and transmitting the virus | There is no evidence that humans have capacity to transmit the virus . A human virus has never been seen infecting both humans and monkeys. | No/ little information available | | |
| Viral stability | Studies show that genetic variability is not in significant parts of the genome that affect vaccine escape. What should be the virus's ability to survive outside the Amazon?. Is the apparent viral stability a factor? In the climate change scenario, what will be the virus's ability to adapt to the adaptations of vectors and hosts? Will the Breves virus in Pará (February 2025) be the same in other places in Brazil in years? | High cost of analyses with public resources, All imported inputs and equipment are expensive | A broad, multidisciplinary and multiprofessional program with integrated results for ongoing assessment. sequence all possible samples | |
| Genetic variability | In the Amazon, the virus tends to remain in mosquitoes, and genetics shows that when the virus leaves the Amazon, variability is greater due to selective pressure on the passage of monkeys and mosquitoes, which occurs in various ways. In the Atlantic Forest, the persistence of the virus is 1 to 2 years and occurs in waves. It is interesting to explain why the virus behaves in a certain way in the Amazon and outside of it. In the Amazon, the virus remains in mosquitoes due to the high temperature for more generations. Outside the Amazon, the viruses remain in mosquitoes for fewer generations and depend on monkeys. The increase in temperature in the southeast may indicate an adaptation now for a greater virus in mosquitoes, as in the Amazon. Here, many infected monkeys in 2018 infect more mosquitoes. Now, with fewer howler monkeys, the dynamics are slower and aggregated to the temperature. All viruses studied are of monkey origin. | It is necessary to obtain more samples from the Amazon and from different areas of Brazil which requires considerable resources | Virus panel for testing and experimental studies. Always create a preprint to save authorship and release it for other groups to use. sequence all possible samples. Support groups in the field and laboratories in analysis | |
| Viral density | The virus varies little, but viral density is higher in some primates and mosquitoes. The frequency of the virus, however, is low in the mosquito population. IEC work with sequencing of 64 samples in press. | Other studies need to be done with a larger number of mosquitoes from other areas of Brazil. | Support groups and laboratories in analysis | |
| Viral preference | There is information for some species of mosquitoes. There is rare information for primates and other possible species that may be involved in the sylvatic cycle. | | Support groups and laboratories in analysis | |
| Speed of viral transmission | The velocity of transmission varies between small fragmented areas (faster) and large fragments (slower). Slower velocity seen for 2024/25 than 2008/9. | The enzootic profile in the Amazon also has an epizootic form that needs to be studied and monitored. The use of samples collected from hunted animals can expand the database of viral circulation among primates and other species. | Support groups and laboratories in analysis | |

**Table A 2. Summary of data gaps discussed in virus.**

| Key Data Gaps | Existence of data | Challenges | Strategy for obtaining | What the data could facilitate |
|---|---|---|---|---|
| Under or over reporting | Large vaccination data bank with records more complete from 2018. However, does not accurately track migration or changing policy. | How to define areas and risk levels given changing populations, staff bandwidth to analyse | Work on communication to public and other institutes. Set up collaboration and data sharing. | Accurate information could allow for better estimates of pre-existing immunity and thus transmission |
| Immunity | Immunity may wane over time - some studies have examined this in subpopulations | Follow up and immunogenicity studies take time, resources and may be at odds with other policies | Existing literature. Assess immunogenicity across risk populations, ethnic groups and age ranges. | Accurate information could allow for better estimates of pre-existing immunity and thus transmission |
| Population at risk | Populations at risk include tourists, ecotourism guides, forest rangers, rural workers, workers in large projects (roads, dams, etc.), environmental police, civil defence. Also people with restrictions on the use of the vaccine (immunosuppressed and others). Data may be available from government environmental institutions, companies, visitor data, tourist mobility and tourists in national, state and municipal conservation units. | Integrating communication an between agencies and balancing political and economic risks | Expand the dissemination of technical notes, disseminate information on social media, carry out campaigns informing about the deadline to guarantee immunity, expand the dissemination of the need for the vaccine in risk areas. Disclose vaccination locations, days and times | Accurate information could allow for better estimates of pre-existing immunity and thus transmission |

**Table A 3. Summary of data gaps discussed in vaccine.**

| Key Data Gaps | Existence of data | Challenges | Strategy for obtaining | What the data could facilitate |
|---|---|---|---|---|
| Travel/ flight capacity | Studies indicate a vertical distribution of 30m for Haemagogus in Amazon. Some studies show mosquitoes can travel up to 11km. Few studies for other vector species | Significant capture effort, well-trained teams for treetop capture, resources for field work and in large areas | i) Studies with mosquito capture on different levels of forests in different biomes and across boundaries of natural areas ii) Carry out captures at different altitudes and conduct experiments in wind tunnels | It would be possible to estimate adaptability to the use of different forest strata in different environments and the use of hosts in different extracts and corridors of transmission and spaces |
| Population data (Number, density, geographic distribution) | IEC has field collection data on paper from 1950s for Haemagogus and Sabethes. It is possible that there are data in biological collections of universities and state museums. It is possible that there are data in old reports from the Rockefeller Foundation and also from SUCAM. Some of this data can eventually be found in SiBBr or SISBio. | Staff bandwidth to systematize data and perform literature reviews. | Formalize a project with resources from CGLAB/MS to gather the Lacens and carry out the survey and organization of the data. Identify a database suitable for this organization. Leverage existing initiatives. | Informing prevalence and ratio of vector to host would improve estimates of transmission intensity and fluctuation. |
| Response to temperature and precipitation | Species diversity and abundance changes with temperature and precipitation. Examples such as data collected from the construction of the Tucurui hydroelectric plant and Ciiu Vale (over a 20 year period) can provide information on temperature and precipitation dependence | Staff bandwidth to analyse data | Experimental studies | Predict areas favourable to viral transmission with greater accuracy |
| Vector life cycles | Mosquitoes take 3 days to digest blood. In the Amazon, there is hatching after 6 months of laying and then in various periods up to 1 year. Sabethes lives for 3 months. In São Paulo, the virus was maintained in 10 generations of mosquitoes. Less is known on larval stages | Significant capture effort, well-trained teams for treetop capture, resources for field work | Field work and experimental studies | Predict areas favourable to viral transmission with greater accuracy |
| Vector behaviour and habitat | Some species in São Paulo, such as Ae. albopictus, are changing their activity period from diurnal to crepuscular. In São Paulo, different species of mosquitoes are distributed between the eastern (forested) and western (fragmented by plantations) areas. | Significant capture effort, well-trained teams for treetop capture, resources for field work | Field work | Predict areas favourable to viral transmission with greater accuracy |
| Vector infectiousness and virus | In São Paulo mosquitoes collected for 2 years kept the virus for 2 months, then no longer. Virus in eggs by vertical transmission. GAL data, which includes thousands of mosquitoes, including males and females, can be used to estimate infectivity, including using barcodes for identification. The data remains in GAL and is not shared. | Data access and staff bandwidth to analyse | Experimental studies, data sharing agreements and collaborations | Predict areas favourable to viral transmission with greater accuracy |

**Table A 4. Summary of data gaps discussed in vectors.**