My journey as a mathematician into public health

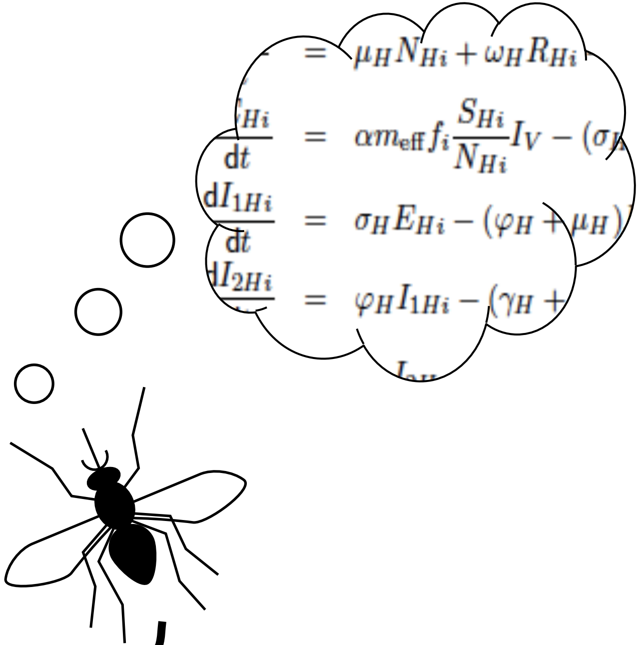
Dr Kat Rock

SBIDER group

On behalf of:

HAT

Modelling & **E**conomic **P**redictions for **P**olicy



PiWORKS Seminar, 30th May 2023

My background

My journey

GCSE

- Maths
- Statistics
- Separate science

I didn't do:

- IT or programming

A levels

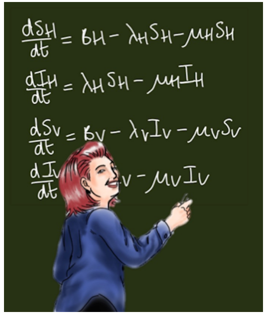
- Maths
- Further Maths
- German
- Music

I didn't do:

- Biology
- French

University

Mathematics

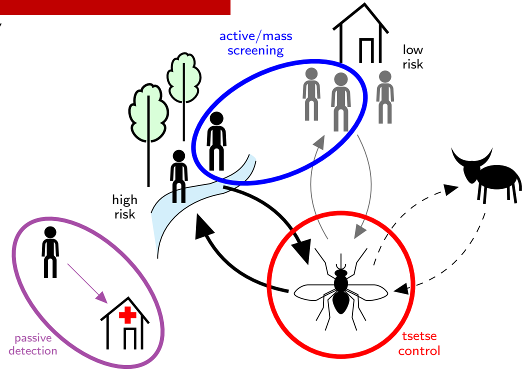


Background:
- ODE theory
- Programming
- Mathematical biology

MMath

Started sleeping sickness research

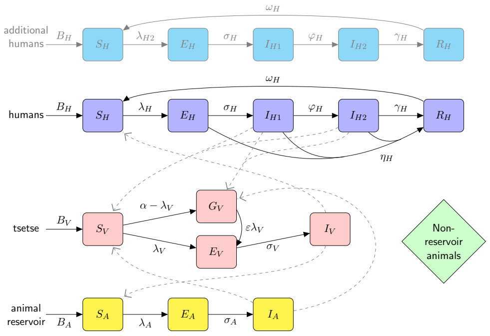
PhD in Mathematical Epidemiology



Epi-modelling methodology:
- Host-only models
- Ross-Macdonald models
- Age- and bite-structured models
- Vector population dynamics

Post docs

Big policy questions:
- When will we eliminate disease?
- Best strategy?
- Problem regions?



Data and fitting:
- Data type
- Fitting process
- Model comparison

Formed my own research team

HAT
Modelling &
Economic
Predictions for
Policy

Started teaching lecture courses

Warwick Zeeman lecturer

Developed new lecture course

Assistant professor

Policy discussions:
- Ministries of health
- WHO
- Bill Gates

Associate professor

Continued updating skill sets:
- Health economic evaluations
- More Bayesian statistics
- French
- Team management and leadership

Reader

Travel

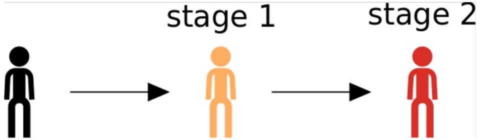

D.N.S.H.P
PROGRAMME NATIONAL
DE LUTTE CONTRE
LA TRYPANOSOMIASE HUMAINE
AFRICAINE
PNLTHA

Modelling elimination of African sleeping sickness

Introduction

Gambiense human African trypanosomiasis (gHAT, sleeping sickness)

- Vector-borne disease, now with very low prevalence – only 747 cases in 2021
- Two distinct stages, with neurological symptoms in stage 2

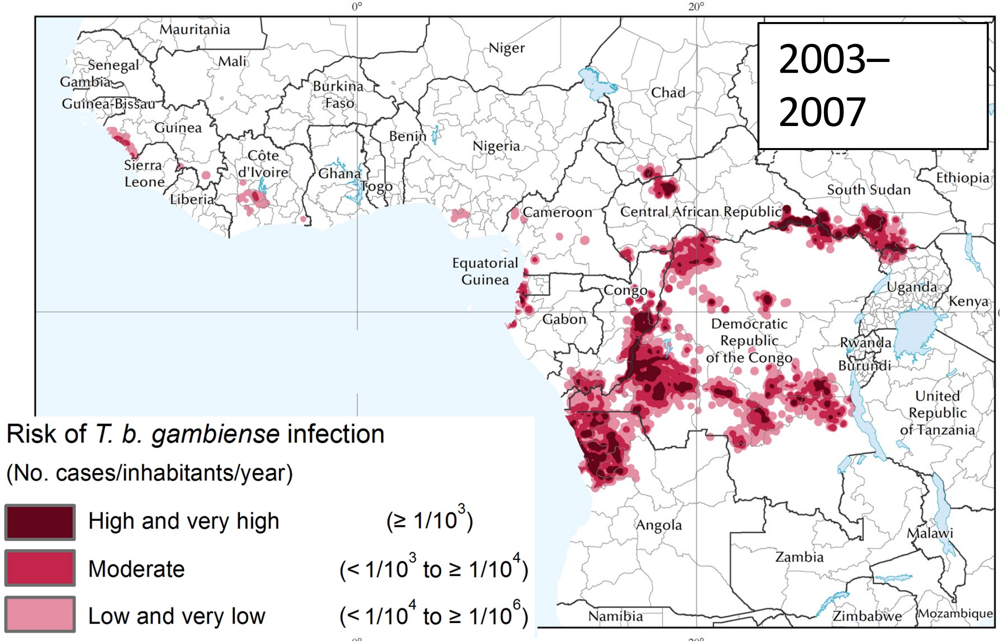


- Typically fatal without treatment
- Endemic in foci across West and Central Africa
- Highest burden in DRC (57% in 2021)

Target: elimination of transmission (EoT) by 2030

- No transmission to humans

Risk of HAT infection



(Simarro et al, PLoS NTD, 2015)

Introduction

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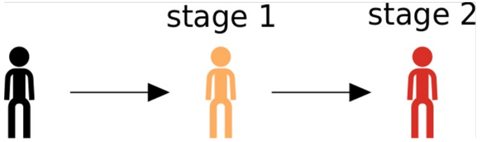

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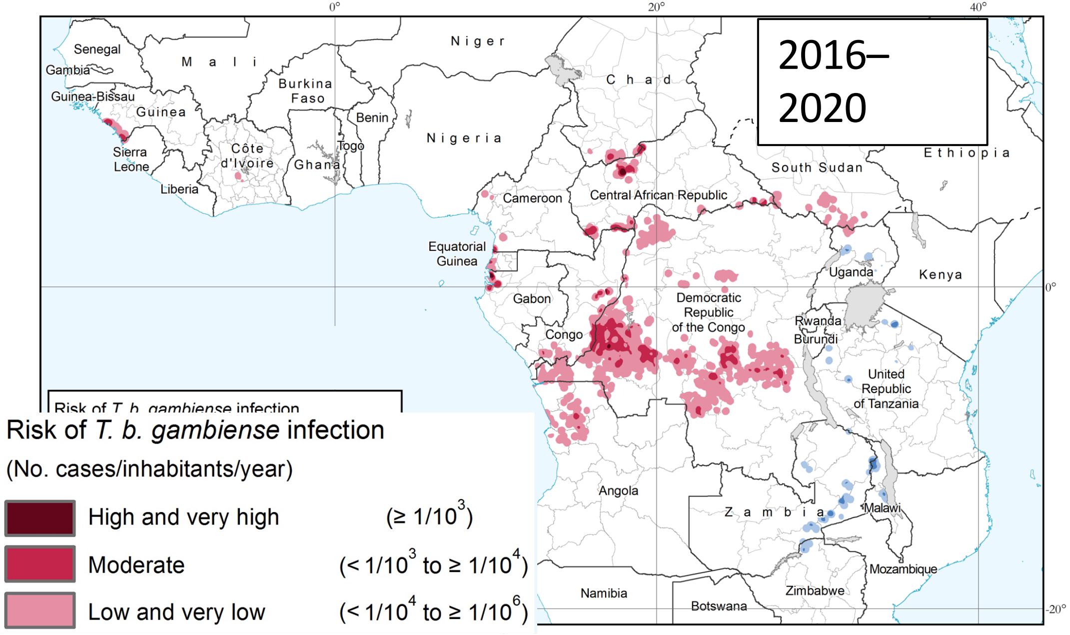
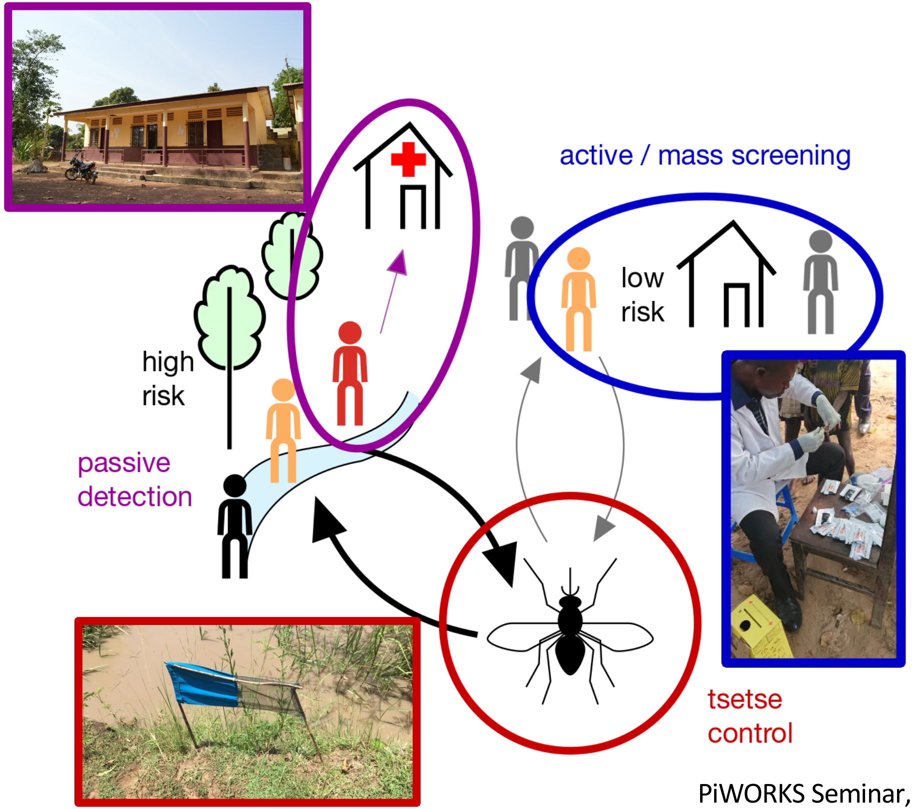


(Franco et al, PLoS NTD, 2022)

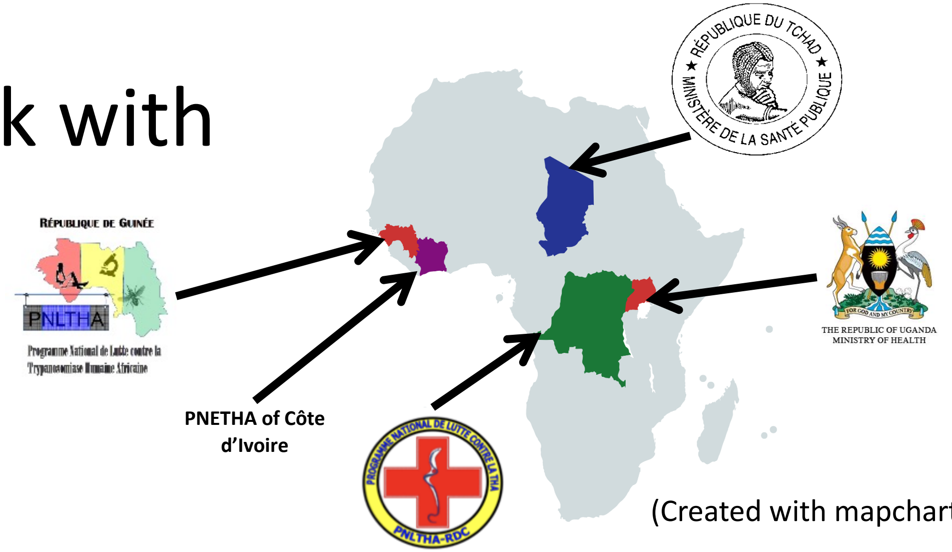
Interventions and assumptions



Challenges

- Data collected by two different modes
- Systematic non-participation
- Possible animal infections
- Unknown asymptomatic contribution
- Sophisticated diagnosis + treatment
  - pentamidine: 7 days
  - NECT: 10 days
  - fexinidazole: 10 days
- Lost to follow-up

Countries we work with



(Created with mapchart.net)

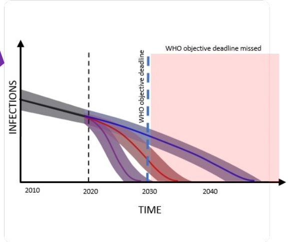
Country	2017	2018	2019	2020	2021
Côte d'Ivoire	3	2	1	0	1
Uganda	0	1	2	1	0
Chad	28	12	16	17	15
Guinea	139	74	69	36	28
Democratic Republic of Congo (DRC)	1100	660	613	395	425

The modelling cycle

A dynamic process

Create or adapt the model

- We undertake a constant cycle of building and refining our model to produce results.
- We evaluate performance based on data and collaborator feedback.

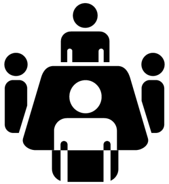


Generate outputs

- Model results are presented in a variety of different ways including in our graphical user interface (GUI)

NEW TOOLS & STRATEGIES

+ NEW DATA



Collate updated information

- New strategies, which may include emerging tools, will be included in model refinements.
- The models will be updated as information changes or new data become available.

Evaluate results with partners

- Regular meetings, at which we discuss modelling results, allow us to further refine model inputs.

Key research questions

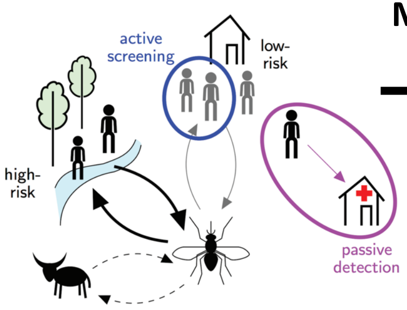
- What can be learned about transmission from data?
  - Key drivers of transmission: non-participation? animals? asymptomatics?
  - How are interventions impacting the route to elimination in different locations?
- What do we expect in the future?
  - Are we on track with current strategy?
  - Can modelling and health economics help optimise future strategy?
- Communicating complex results for policy
  - How can modelling support programme operationalization?

What drives gHAT dynamics?

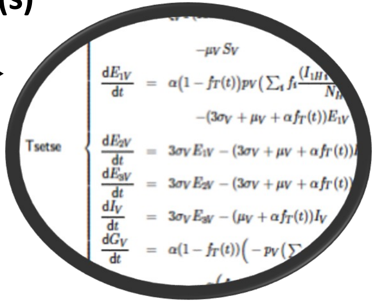
Calibration of the model to case data

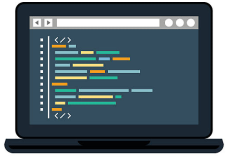
- Annually varying intervention effort
  - particularly active screening
- Geographically varying intervention effort
  - active screening coverage
  - strength of passive health system to detect people
  - presence of vector control
- Missing data
  - mainly number of people actively screened in early 2000s (must be imputed)
  - no sufficiently specific (or routine) data on infections in animals
- Extra useful data (sometimes present)
  - “staging” of cases to help better match models to proportion in early or late disease

Calibration of the model to case data

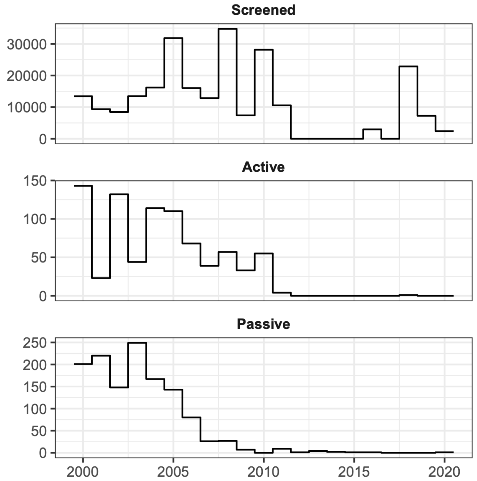


Model(s)

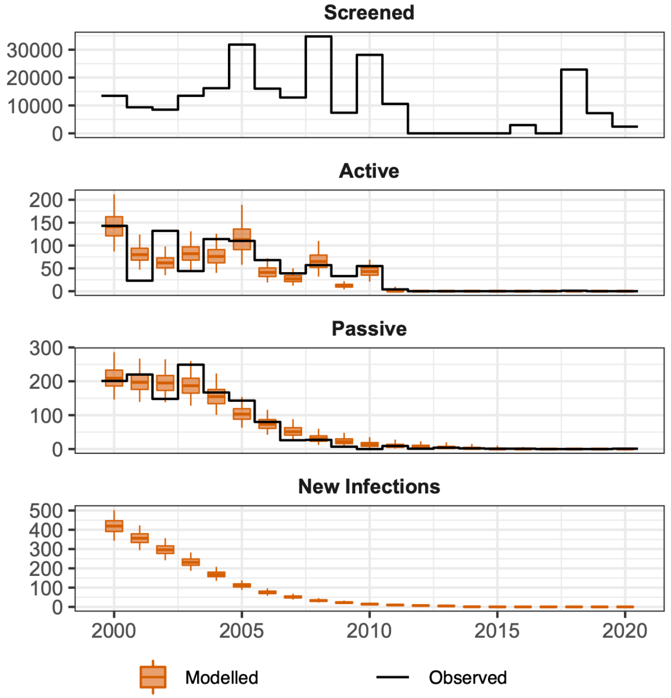




Data



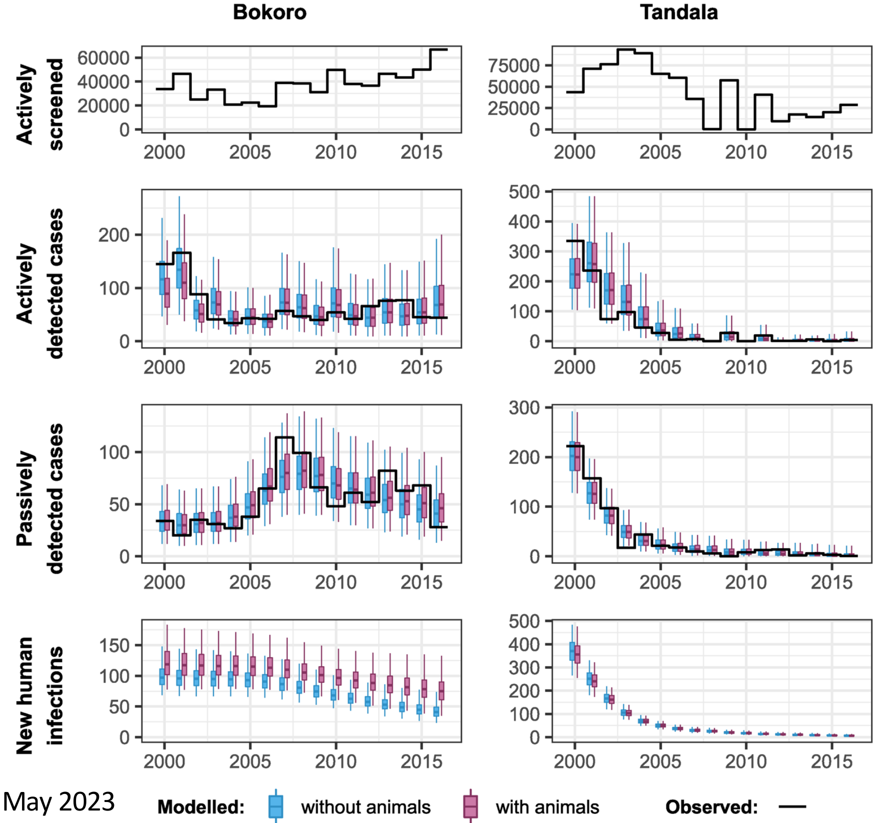
Adaptive MCMC



Cryptic reservoirs: role of potential animal transmission

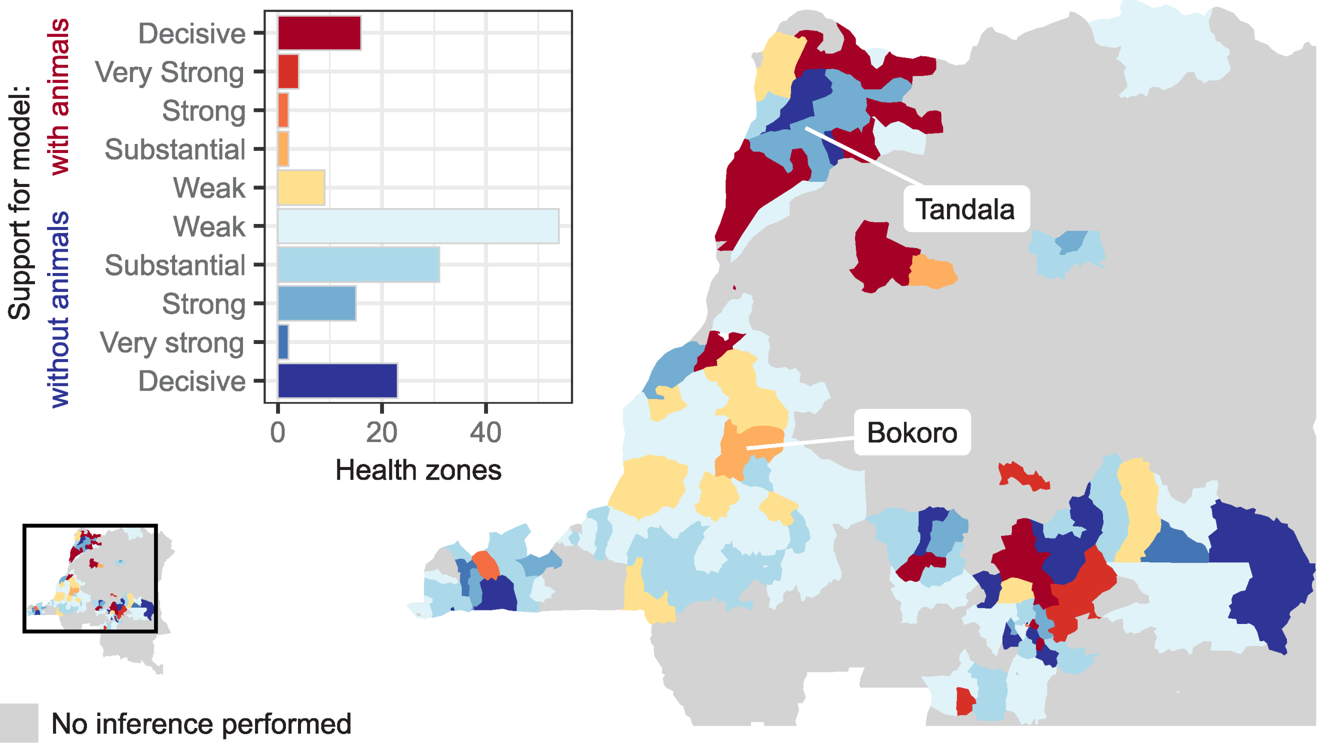
(Crump et al, PLoS NTD, 2022)

- We can compare the fits of the “best” models with high/low risk and participation structure with and without animal transmission
- They look very similar in case reporting
- But underlying new infections can look quite different
- What host group is driving transmission in the “with animal” case?



Cryptic reservoirs: role of potential animal transmission

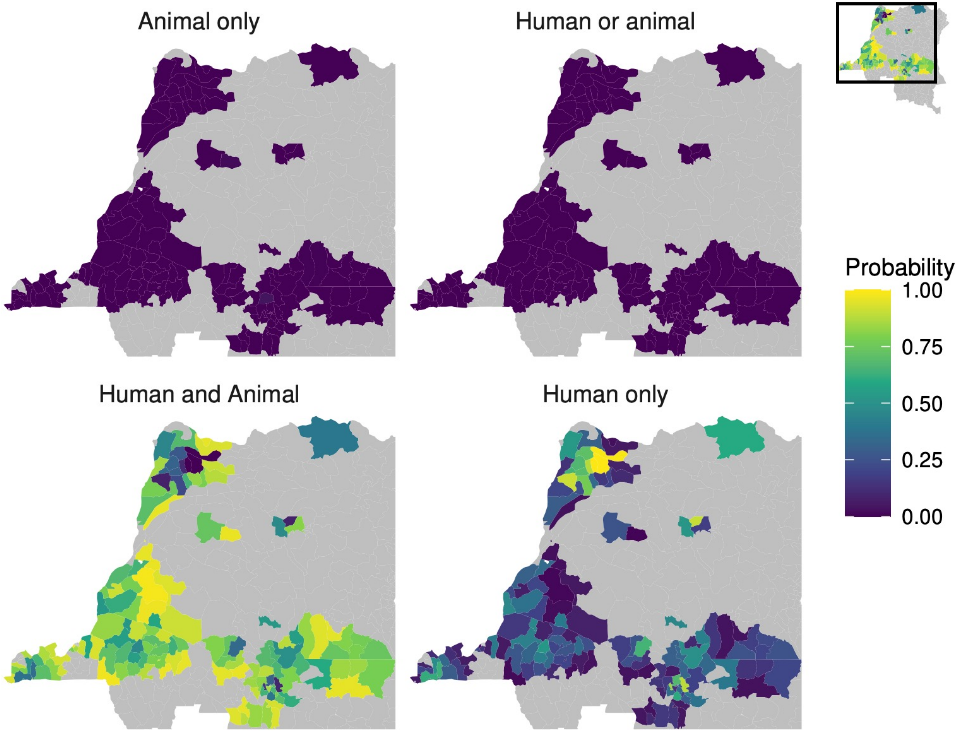
- We can examine the model evidence for or against animal transmission across lots of health zones
- We do this using Bayes factors



(Crump et al, PLoS NTD, 2022)

Cryptic reservoirs: role of potential animal transmission

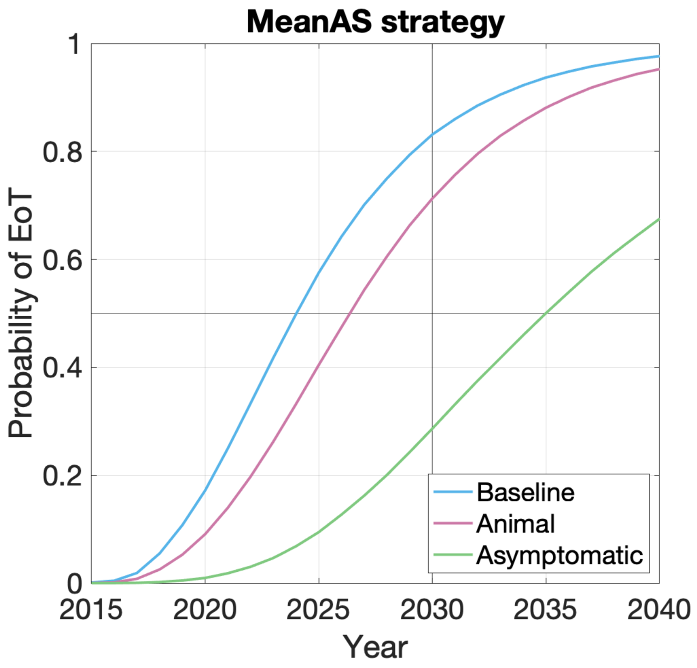
- We have no data on animals
- Highly unlikely that animals could maintain transmission by themselves
- Human transmission is needed for maintenance
- Animal transmission may slow down EoT
- Interventions that impact transmission in all hosts helpful



(Crump et al, PLoS NTD, 2022)

Cryptic reservoirs: asymptomatic human infections

- We can also fit model variants including transmission to and from asymptomatic humans
- Amongst our well-fitting models, the asymptomatic model is most pessimistic about EoT
- Vector control beneficial, but expensive to carry out widely
- Model fits are continually being updated as new data are available

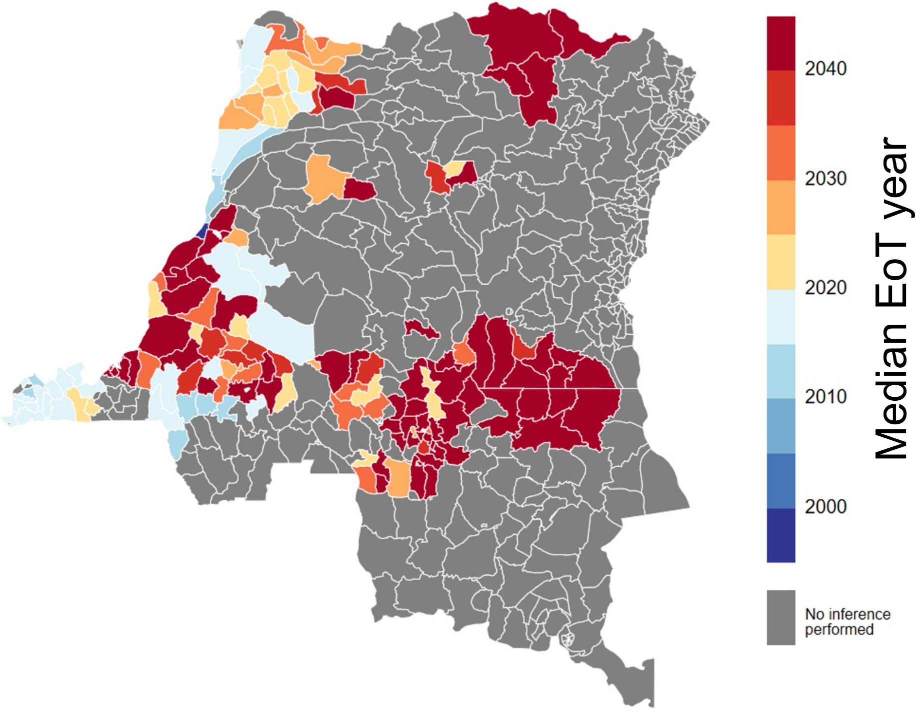


(Aliee et al., In prep)

What different approaches might be needed for EoT?

Are current strategies sufficient for EoT?

- For each health zone we projected continuation of the current strategy using posterior parameterisation
- Many regions appear on track to meet EoT by 2030
- Some may require intensified interventions to have high confidence of achieving the goal



(Huang et al, Nat Comms, 2022)

Are current strategies sufficient for EoT?

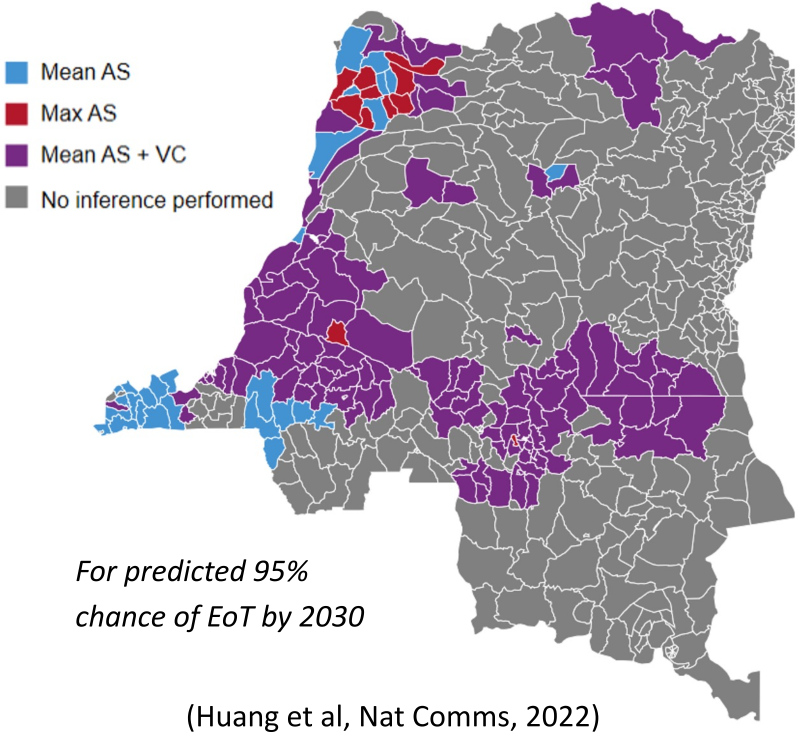
- In one analysis we considered four different strategies made up of combinations of interventions

Interventions

Strategies	**Active screening coverage**	**Passive screening**	**Vector control**
MeanAS	Mean of last 5 years	Continues	None
MaxAS	Maximum ever	Continues	None
MeanAS + VC	Mean of last 5 years	Continues	80% reduction
MaxAS + VC	Maximum ever	Continues	80% reduction

Are current strategies sufficient for EoT?

- We simulated all strategies in all regions and looked at the "least ambitious" way to get to EoT with >95% in each region
- We assumed that increasing active screening coverage was always cheaper than adding vector control
- Our results indicate that in many place we might need to do more than just increase screening level

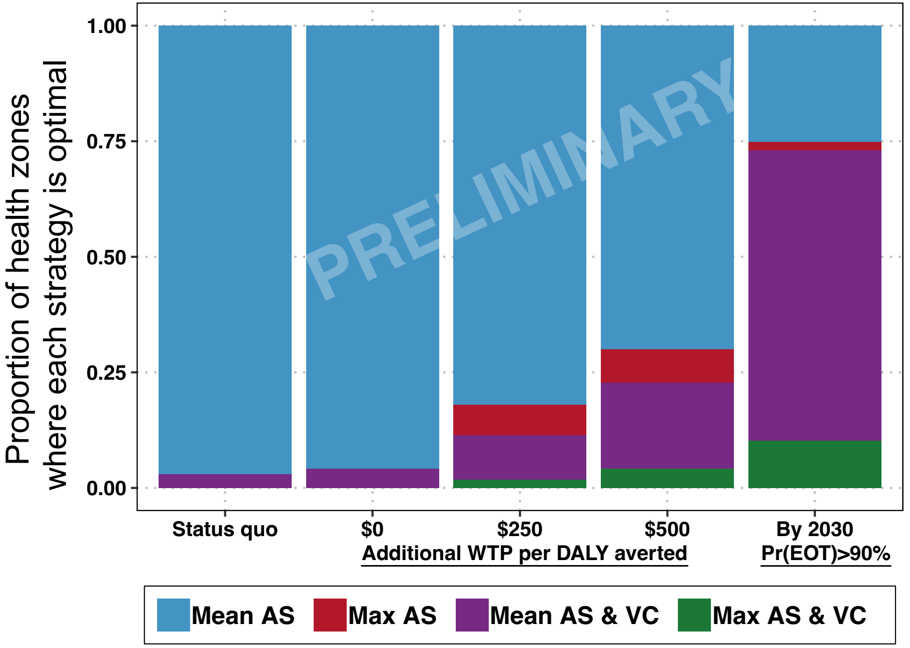


For predicted 95% chance of EoT by 2030

(Huang et al, Nat Comms, 2022)

What's a cost-effective gHAT strategy?

- Although "cost-effective" strategies may also lead to EoT by 2030, this is not the case in all regions
- This analysis also depends on how confident the policy-maker would like to be in meeting the EoT goal
- There is still a large difference between the number of health zones predicted to need intensified strategies and those where is it "cost-effective"

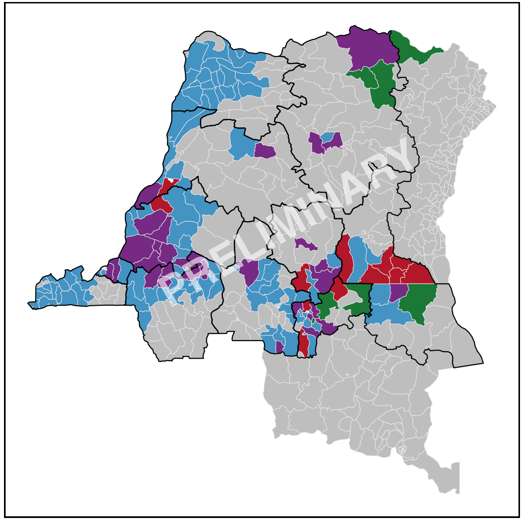


(Antillon et al, In prep)

What’s a cost-effective gHAT strategy?

- Even at a high “willingness-to-pay” (WTP) for the DRC, we might not recommend strategies likely to lead to EoT by 2030

Additional WTP: $500 per DALY averted



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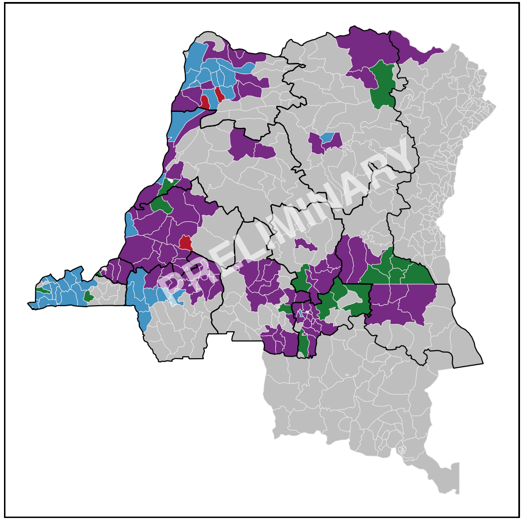
Pr(EOT by 2030)>90%



- Mean AS
- Mean AS + VC
- Max AS
- Max AS + VC
- No analysis performed

(Antillon et al, In prep)

Our graphical user interface (GUI)

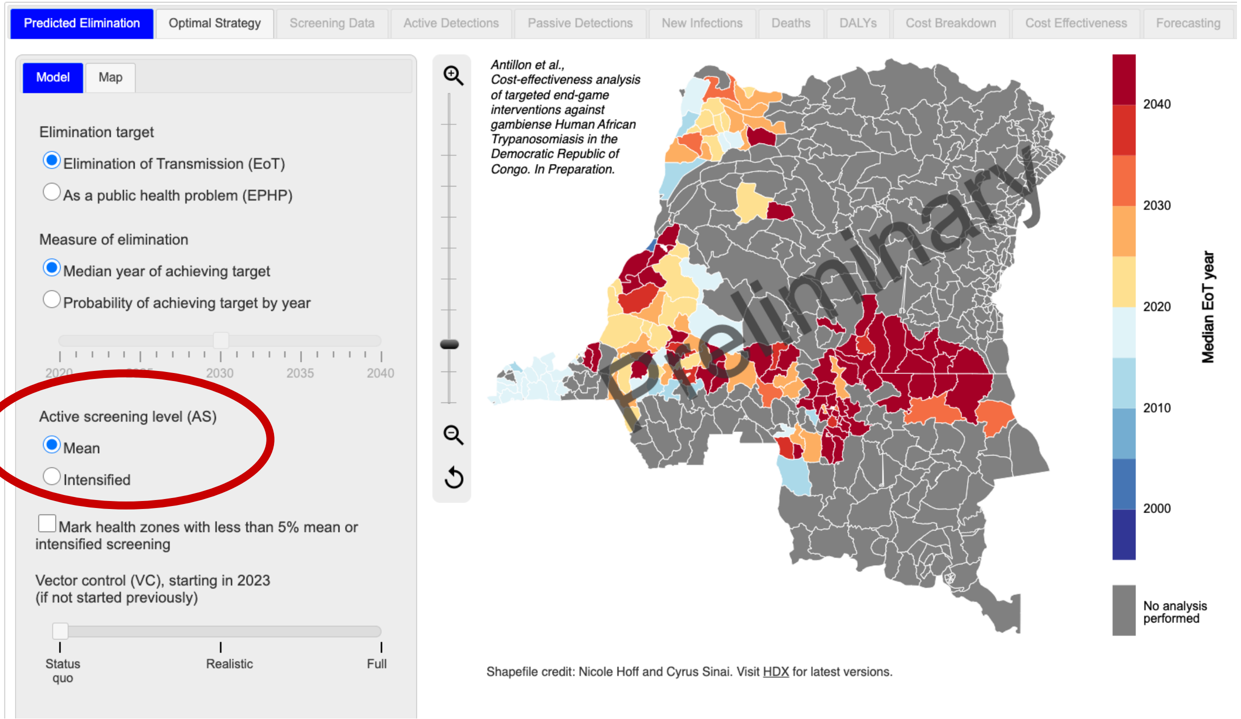
Our graphical user interface (GUI)

- A big challenge is communicating the vast array of results in a straightforward way:
  - In the DRC alone we have 168 health zones and in each we had four strategies.
  - We might want to show numbers of cases we expect in active or passive screening and the number of new infections each year + uncertainty
- Our tailor-made GUI enables us to do this and can be continually updated as we acquire new data and update results

Publicly available

Url: https://hatmepp.warwick.ac.uk/projections/v2/

GUI demonstration



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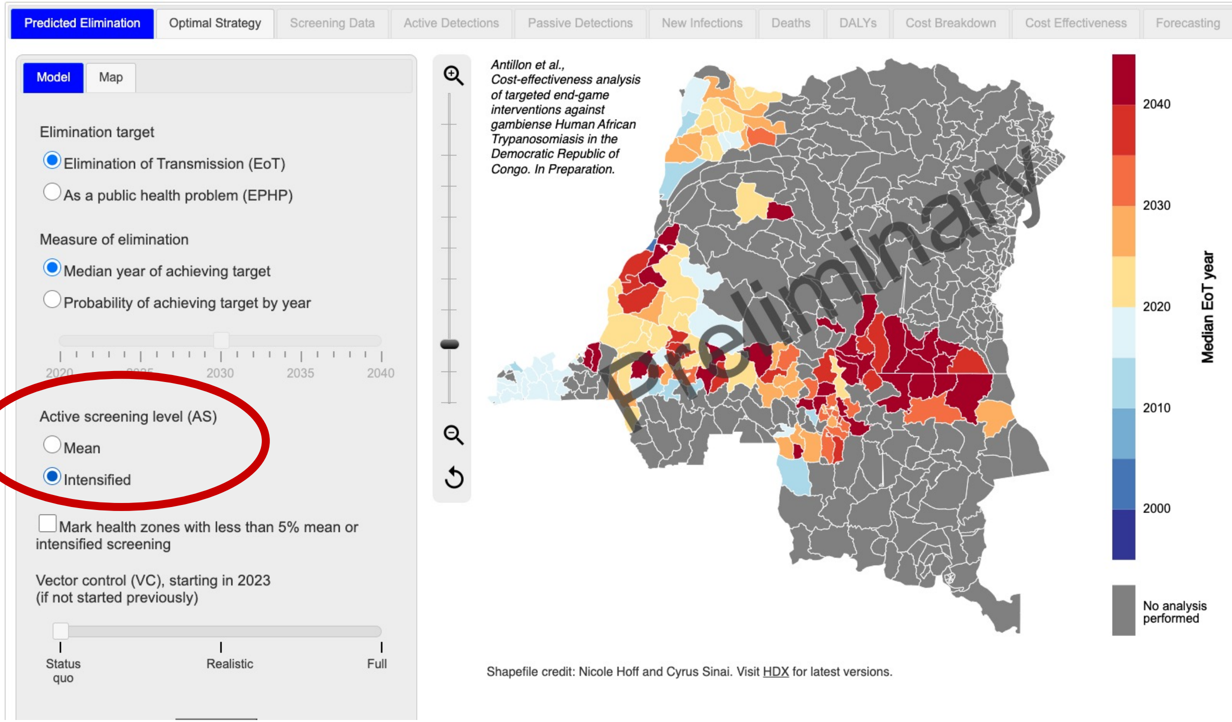
GUI demonstration



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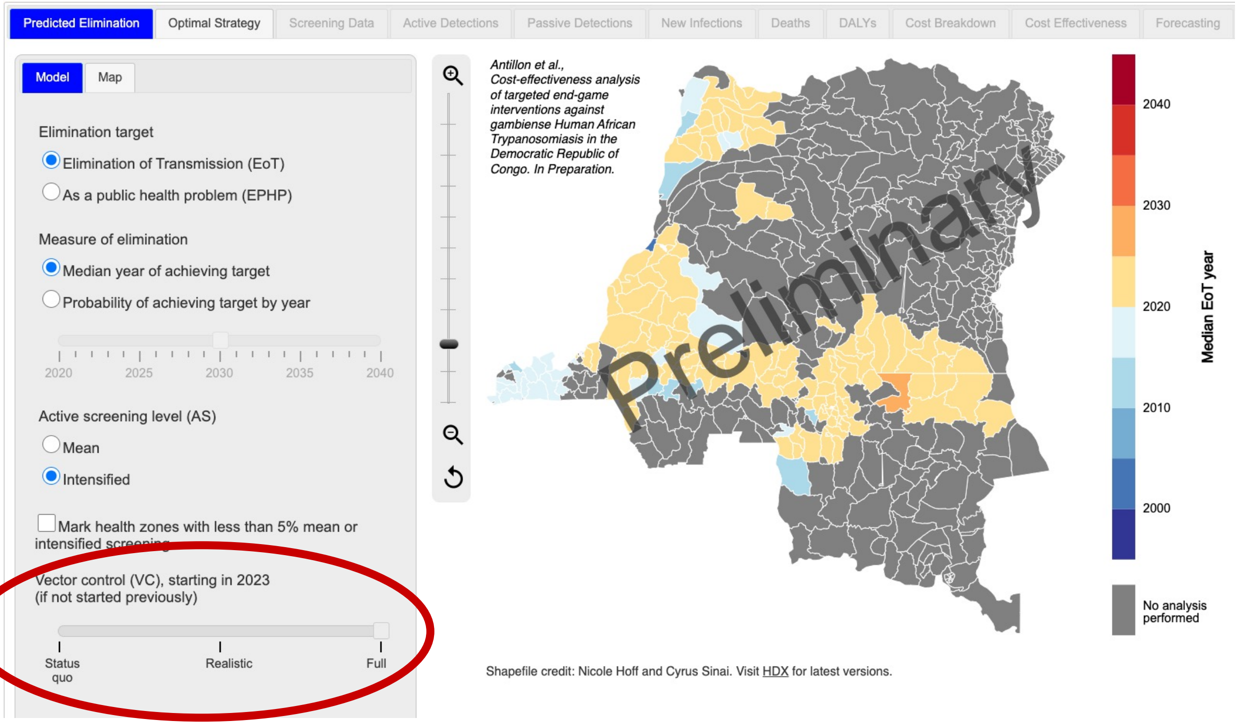

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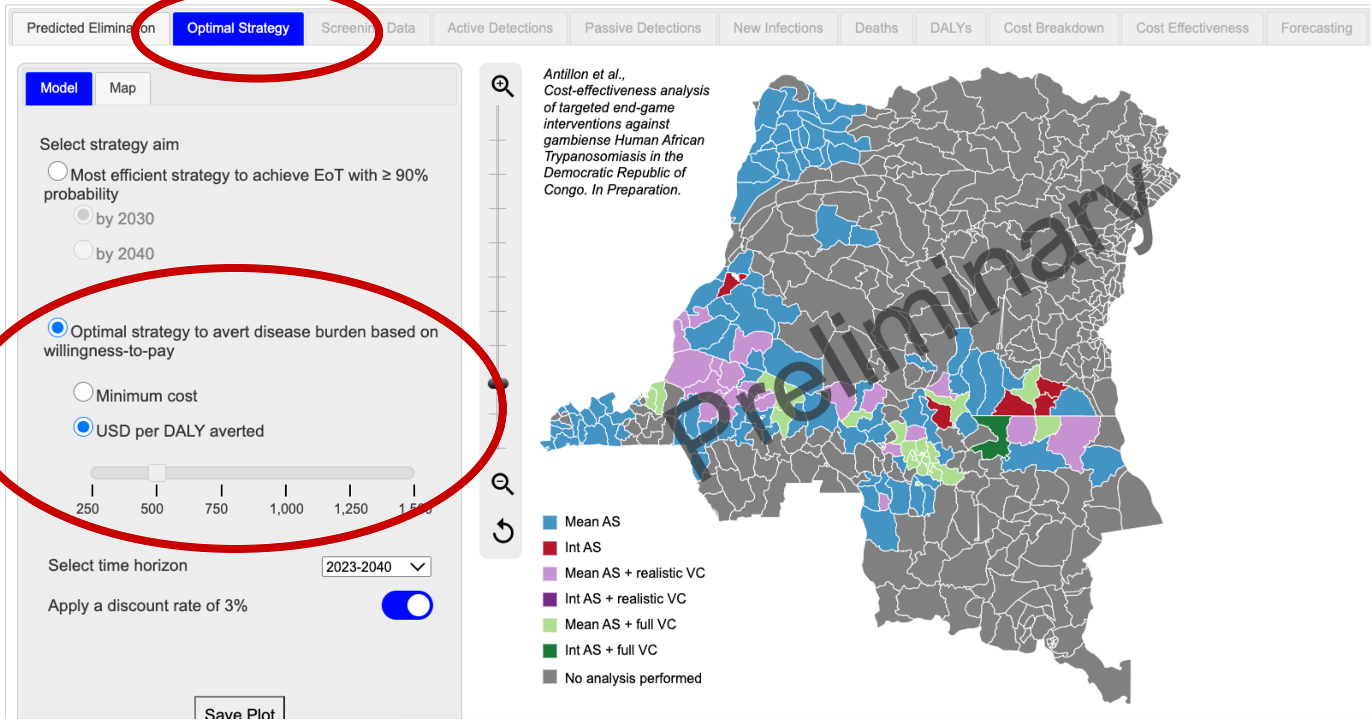

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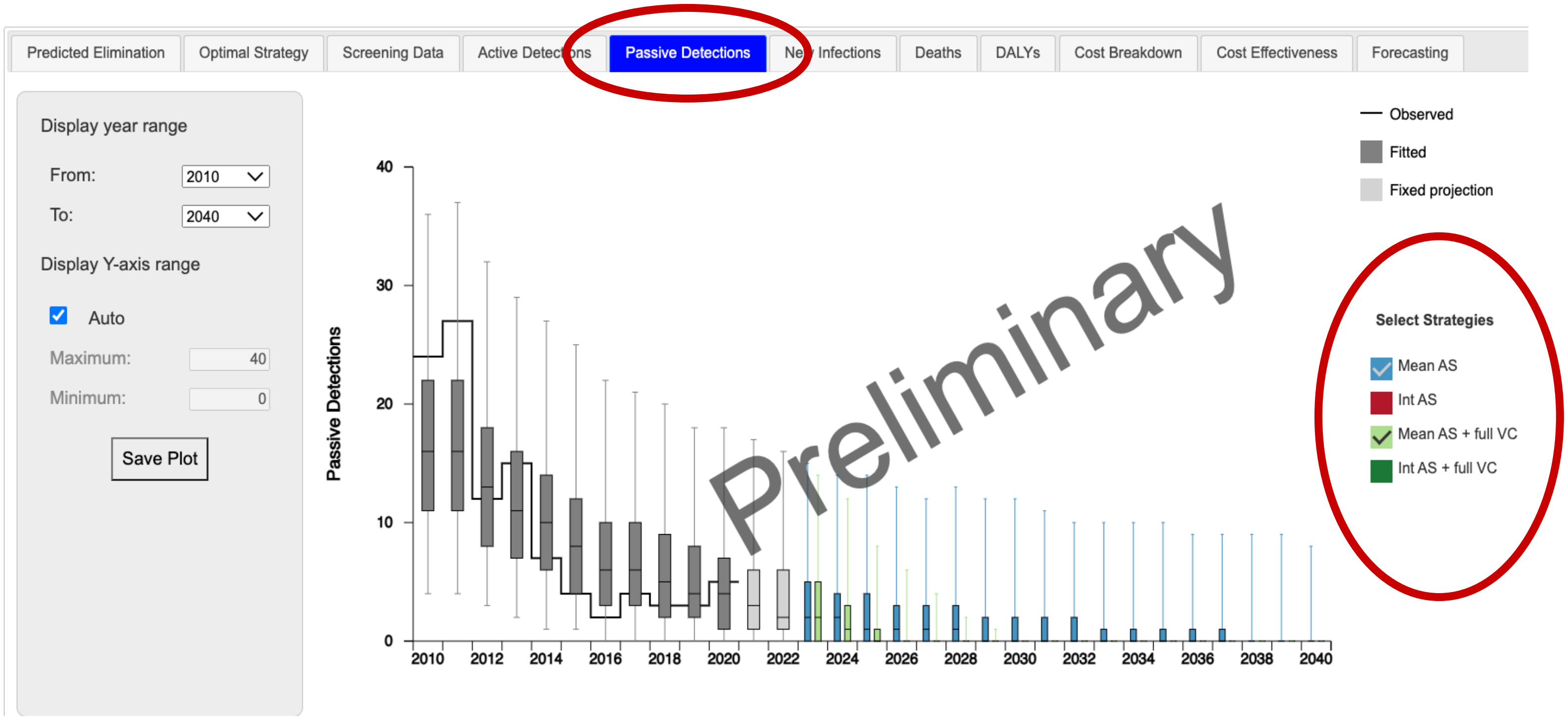

Forecasting tool use

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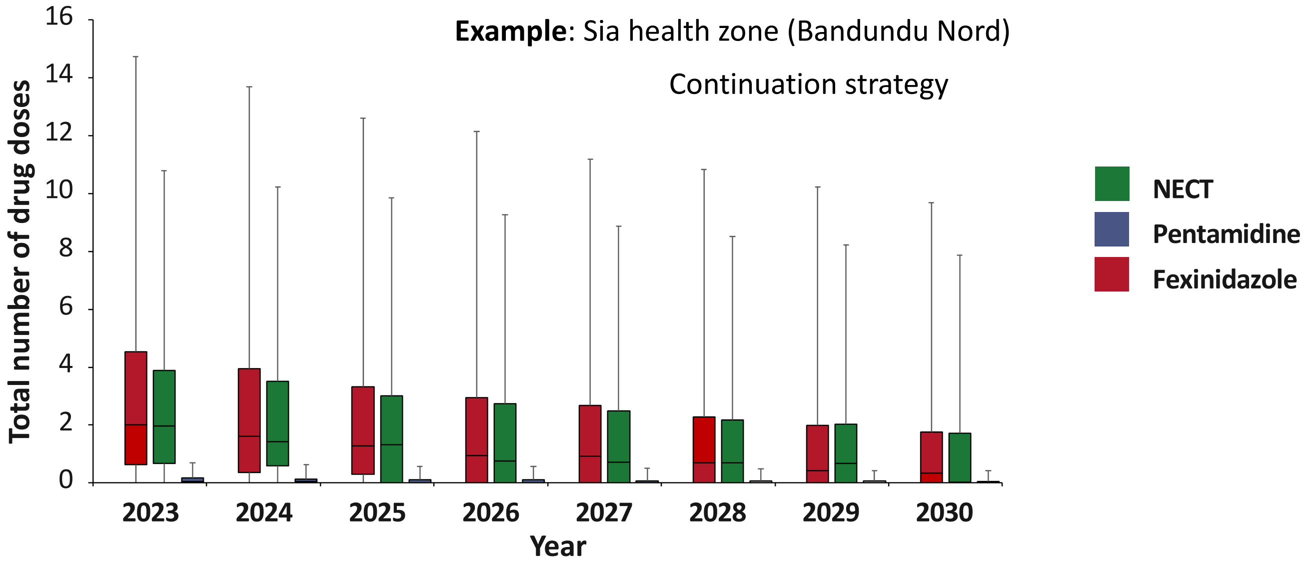
Forecasting tool use

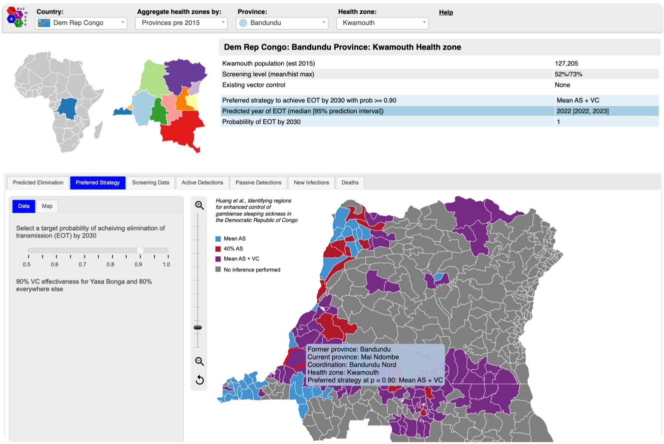
- Our modelling can be used to output expected numbers (and uncertainty) under a specific strategy for a specific location
- This would mean we have some idea of an upper limit of doses that might be needed in each health zone



A continual cycle…

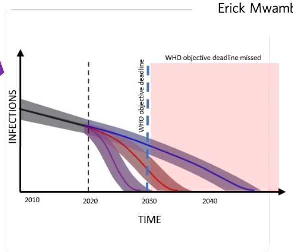
The modelling cycle

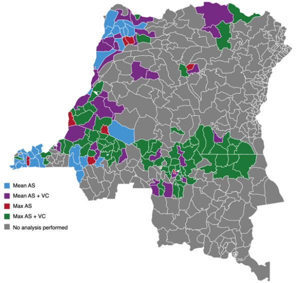
A dynamic process



Identifying regions for enhanced control of *gambiense* sleeping sickness in the Democratic Republic of Congo

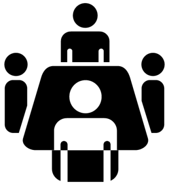
Ching-I Huang[1,2,6], Ronald E. Crump[1,2,3,6], Paul E. Brown[1,2], Simon E. F. Spencer[1,4], Erick Mwamba Miaka[5], Chansy Shampa[5], Matt J. Keelin





NEW TOOLS & STRATEGIES

+ NEW DATA



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Acknowledgements

HAT MEPP

Oxford Team

RESEARCHERS

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INSTITUTE OF TROPICAL MEDICINE ANTWERP

IRD Institut de Recherche pour le Développement FRANCE

World Health Organisation

FIND Because diagnosis matters

CIRDES

THE REPUBLIC OF UGANDA MINISTRY OF HEALTH

PNLTHA (Guinée)

PNLTHA of Chad

PNETHA of Côte d'Ivoire

PNLTHA-RDC

Dr Alex Shaw

IPR (Institut Pierre Richet) Centre de Recherche

INSP

Trypa-NO! Working together to eliminate sleeping sickness

FUNDING

Bill & Melinda Gates Foundation

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Thanks for listening!

k.s.rock@warwick.ac.uk

@DrKatRock

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