Modelling framework to demonstrate elimination of a vector population: tsetse elimination in Chad



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How do we *demonstrate* that we have achieved elimination?

Progress

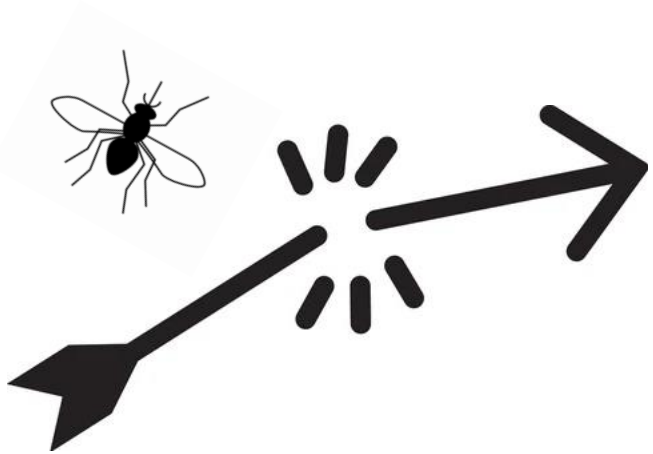
The WHO has validated gHAT EPHP in 10 countries



Countries that have eliminated gHAT as a public health problem

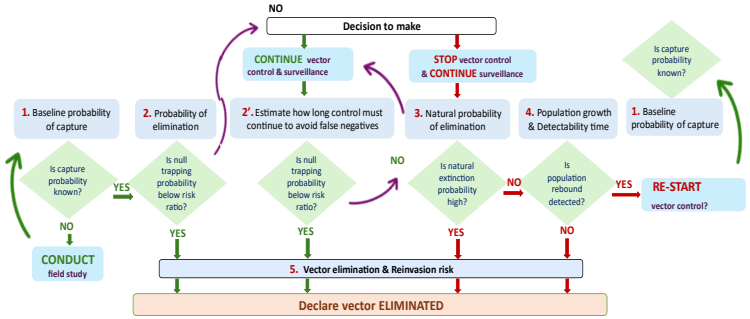
The lingering threat

The 2030 EoT goal is threatened by the vector that remains

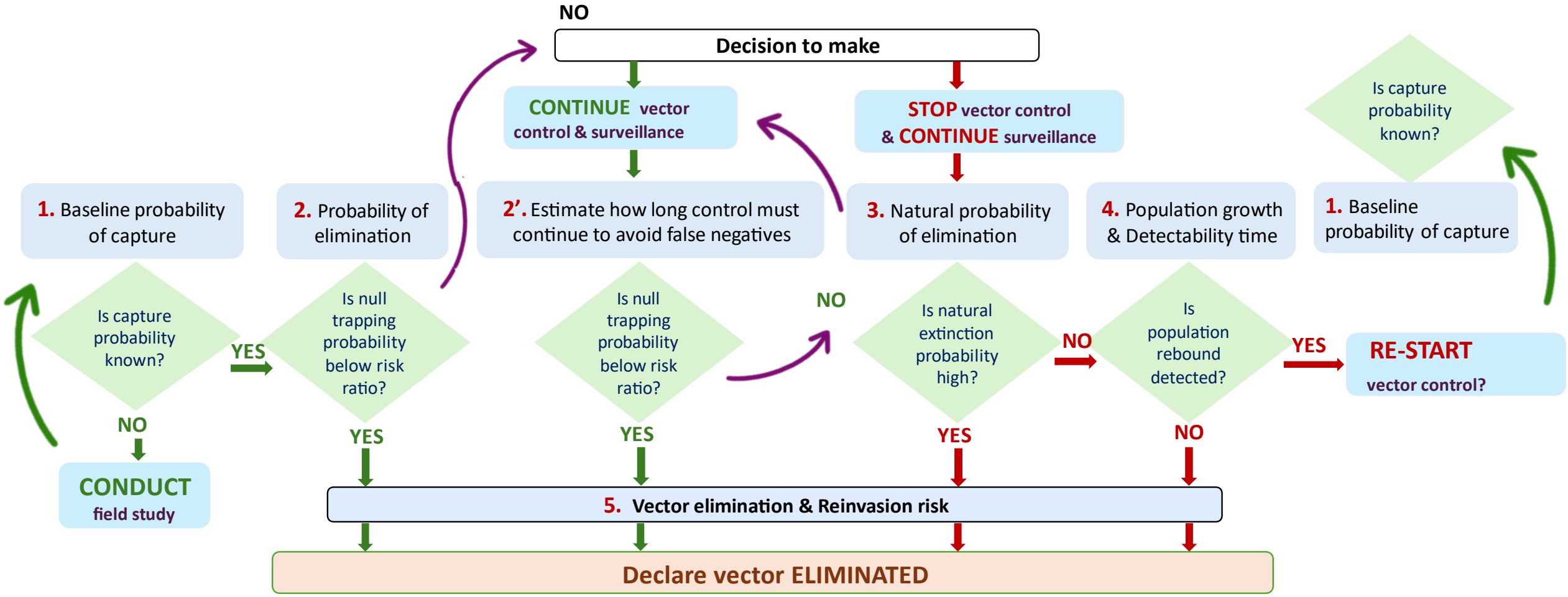


Our framework

Moving beyond a "wait and see" approach, a rigorous **new model to formally demonstrate tsetse elimination**



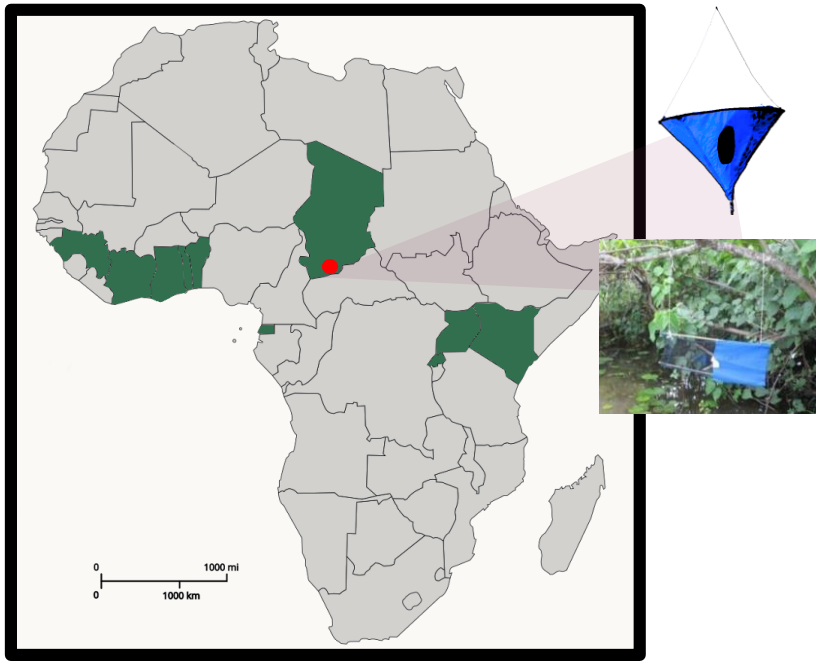
Modelling framework and decision tree for demonstrating vector elimination



Case study: gHAT and *Glossina fuscipes fuscipes* control, Mandoul, Chad

The Mandoul region

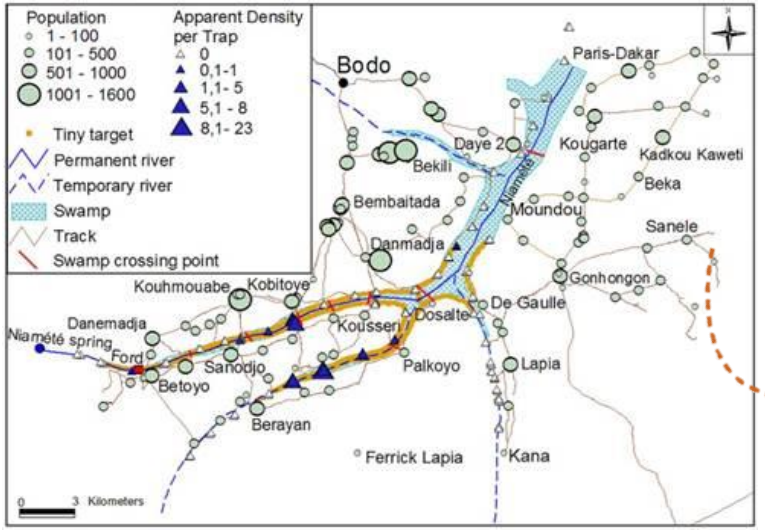
Genetically & geographically Isolated tsetse



The intervention

Intensive control and surveillance efforts since 2014:

- 2700+ **Tiny Targets** (removed in 2025)
- 44 traps, 2 days, 2 times/year



The result

No tsetse caught since 2018

Zero!



Mahamat, M.H. *et al.* (2017) Adding tsetse control to medical activities contributes to decreasing transmission of sleeping sickness in the Mandoul focus (Chad). *PLoS Neglected Tropical Diseases* **11**(7): **e0005792**.

Step 1: Probability of capture

Big Chamaunga Island, Lake Victoria, Kenya

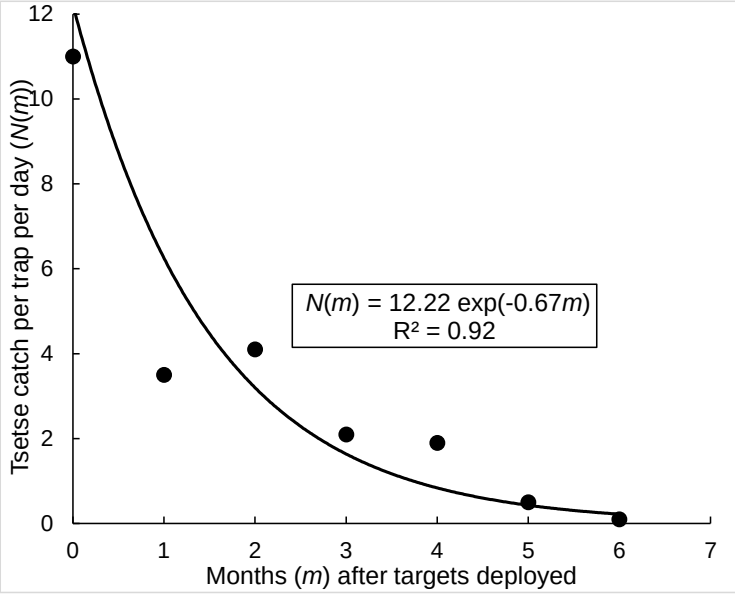
Tiny targets kill ~ 4% of female flies per day

Each target kills 0.14% of all flies per day

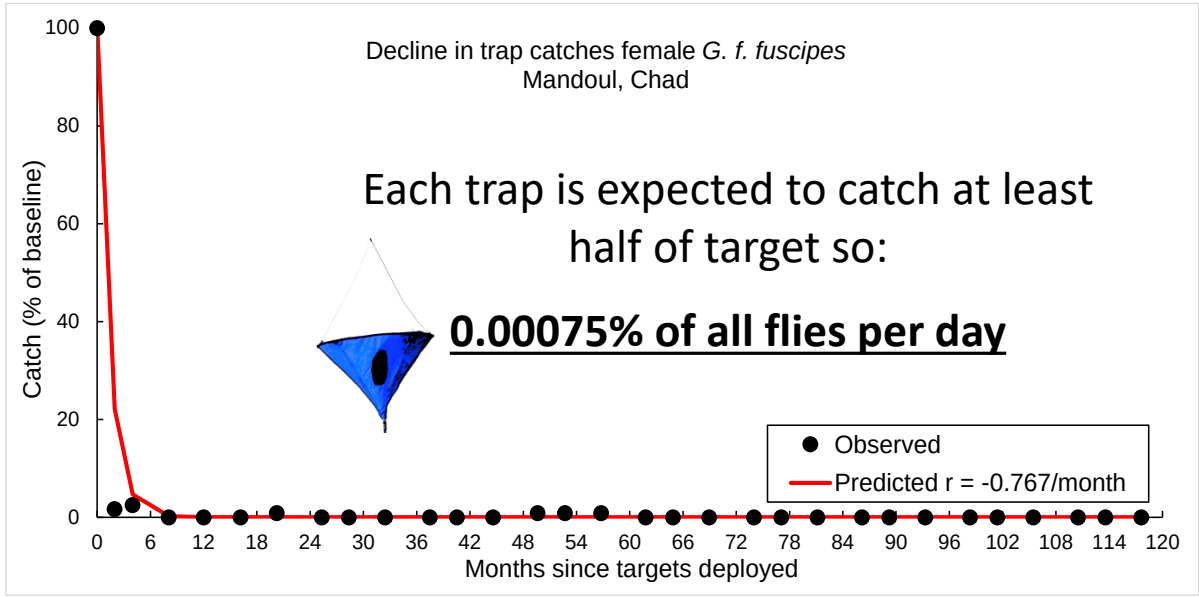
Mandoul, Chad

Tiny targets kill ~ 4% of female flies per day

Each target kill (1 - 0.96)^(1/2713) = 0.0015% flies per day



Decline in numbers of female G. f. fuscipes trapped on Big Chamaunga Island, following the deployment of 30 Tiny Targets on the 1.5 km perimeter of the island.



Observed catches of adult G. f. fuscipes in biconical traps in Mandoul, and the expected numbers if the growth rate was taken to be -0.767 per month.

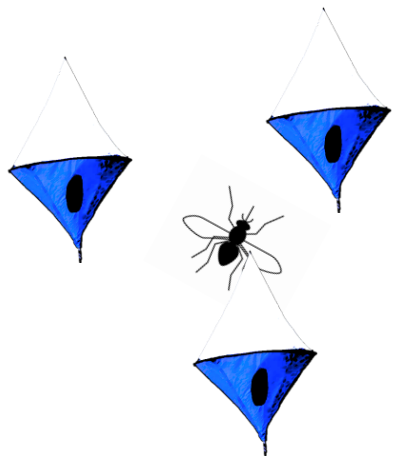
J. W. Hargrove, Extinction probabilities and times to extinction for populations of tsetse flies Glossina spp. (Diptera: Glossinidae) subjected to various control measures. Bull. Entomol. Res. ***95****, 13–21 (2005).*

Step 2: Probability of elimination of the tsetse population under control

Probability C' of observing a series of zero catches when at least one tsetse remains

$$C'(N, S, \sigma, t) = \exp(-\frac{St\sigma N}{A}) = \exp(-St\sigma\lambda)$$

A Area sampled (km2)
N Total insects surviving the eradication attempt
σ Trap efficiency (step 1: 0.0000075**)**
S Number of traps present (in A)
t Number of days for which each trap is operated
$\lambda = \frac{N}{A}$ tsetse density

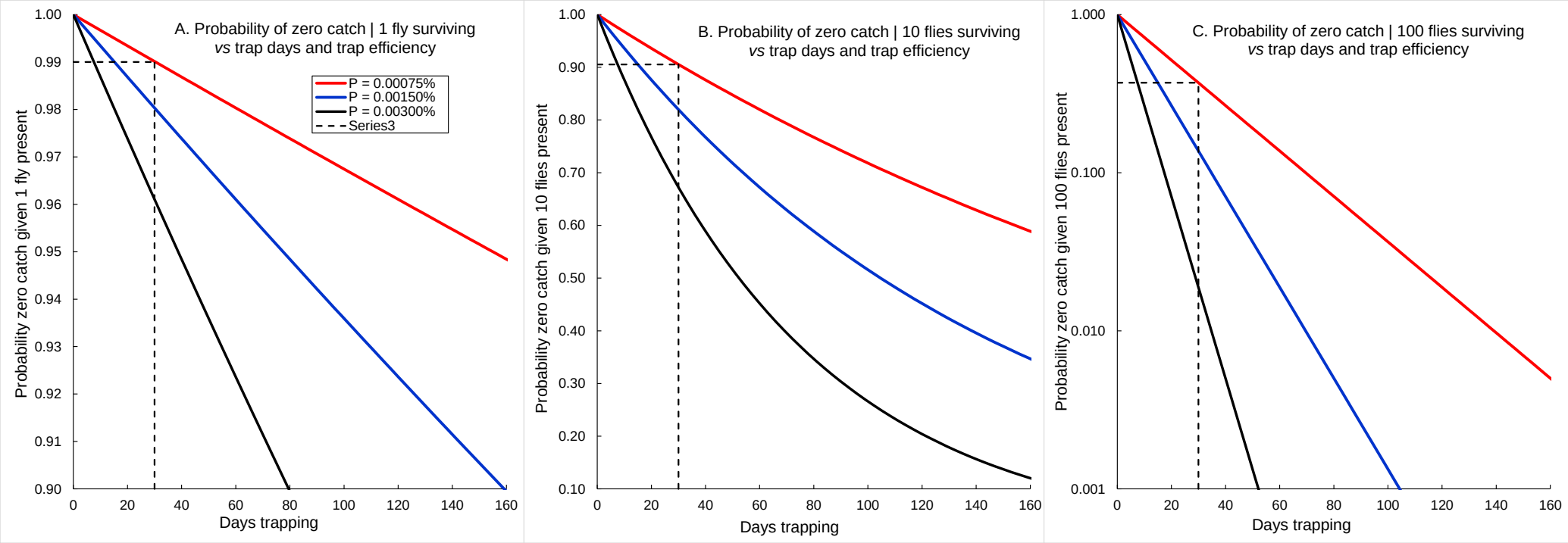


If C' is sufficiently low (0.1 or 0.01): a very low probability that we have a false negative ➡ **tsetse elimination**

H. J. Barclay, J. W. Hargrove, Probability models to facilitate a declaration of pest-free status, with special reference to tsetse (Diptera: Glossinidae). Bull. Entomol. Res. ***95****, 1–11 (2005).*

Step 2: Not yet the case for Mandoul

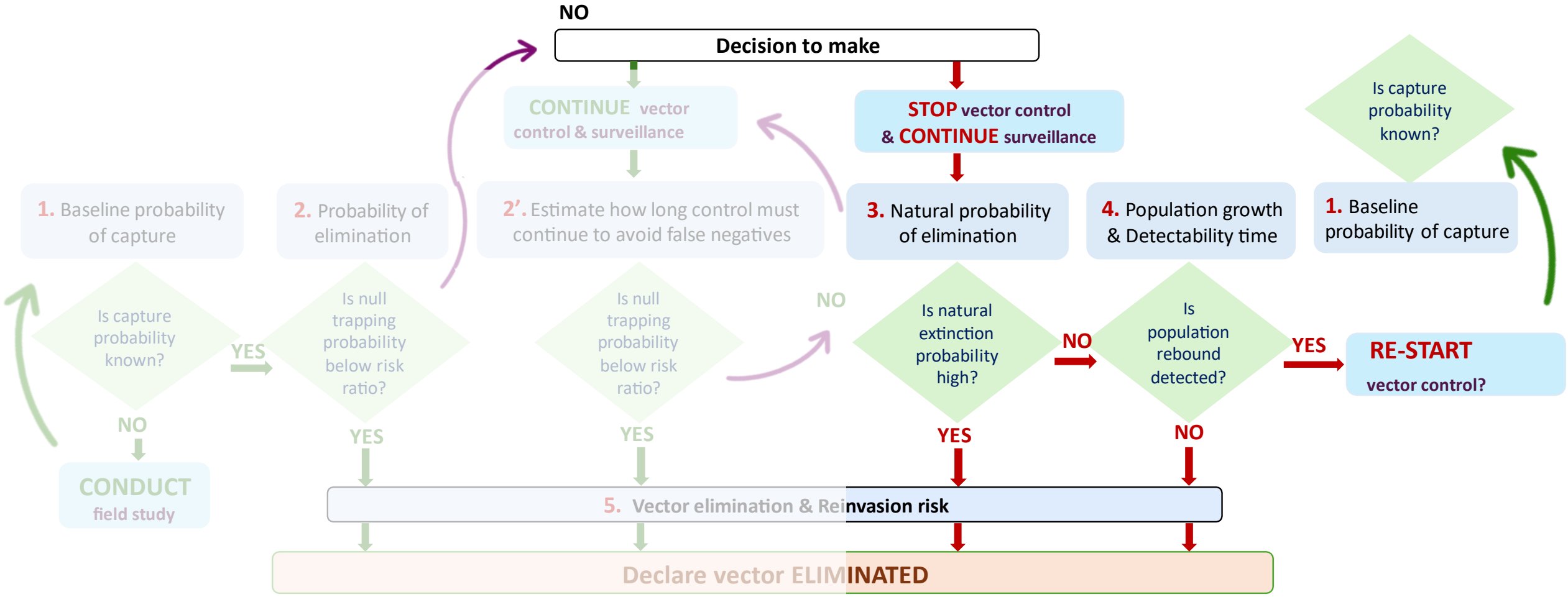
- $((1-0.0000075)^{44})^{30}$ =0,991 so 99.1% chance of failing to catch one surviving fly
- 90% and 37% for 10 and 100 remaining flies respectively



Step 2': pursuing vector control and vector surveillance until 99% confident of tsetse elimination

13,900 days (40 years of continuous trapping) to be 99% confident not to have missed a single fly (C' <0.01)

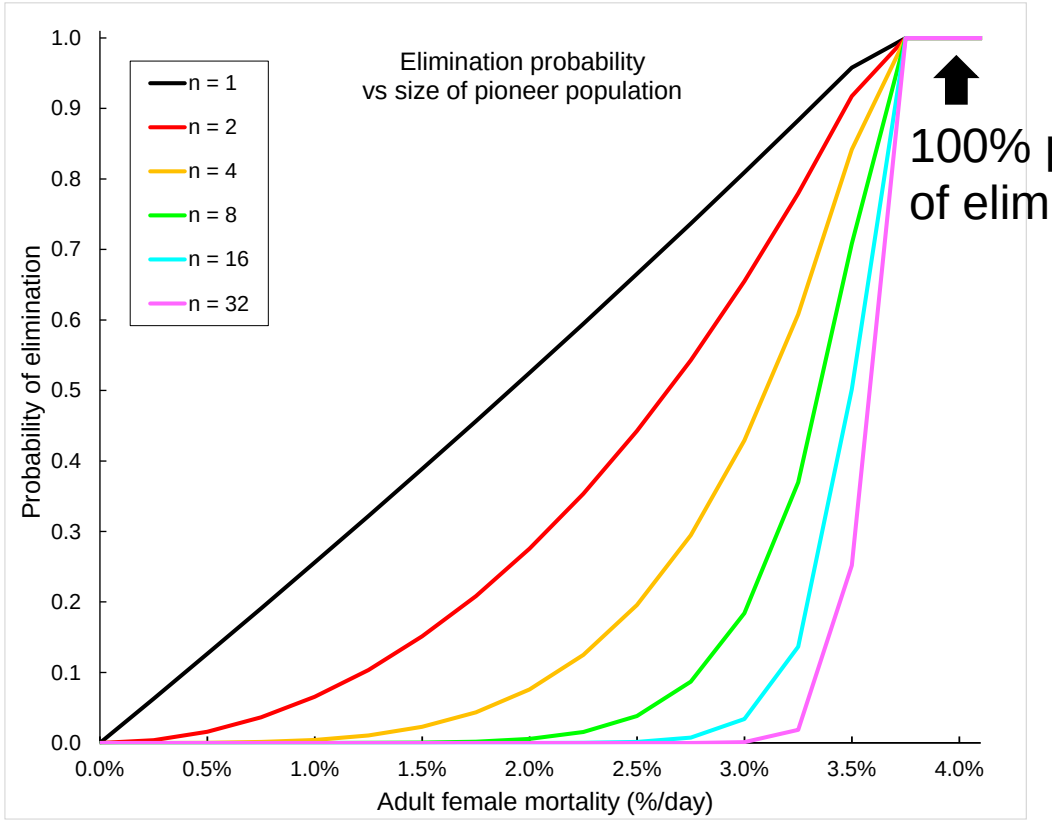
Modelling framework and decision tree for demonstrating vector elimination



Step 3: Probability of natural elimination of a tsetse remnant population in Mandoul

➡ Unwise to rely on a remnant population being eliminated by chance in Mandoul

- 2% per day mortality, <10% for 10 inseminated female tsetse to disappear by chance.
- Even if still 3% per day, <10% for 16 female.

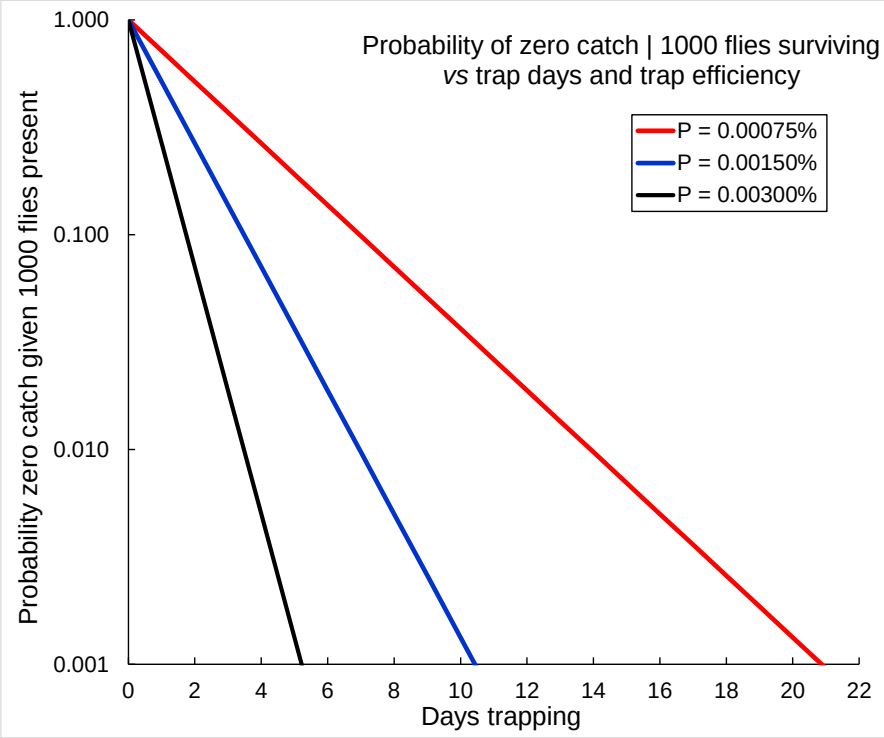


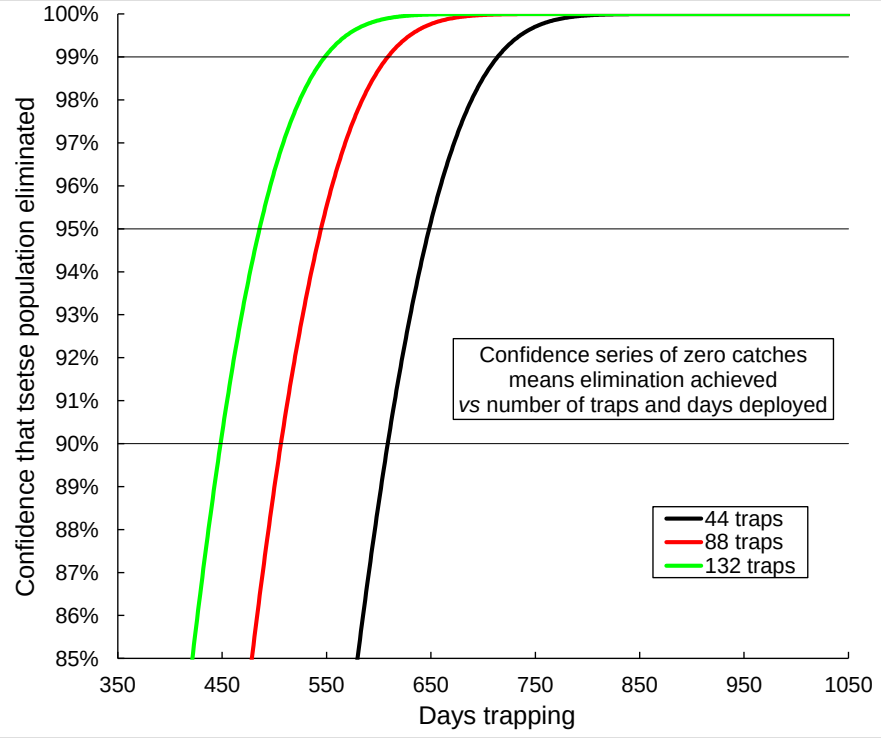
E. B. Are, J. W. Hargrove, J. Dushoff, Does Counting Different Life Stages Impact Estimates for Extinction Probabilities for Tsetse (Glossina spp)? Bull. Math. Biol. ***83****, 1–13 (2021)*

Step 4: Allowing for the detection of a post-vector-control rebound

Tiny Targets removal in 2025 ➡ Population rebound to 1000 tsetse in 2-3 years

- 44 traps for 21 days would catch at least 1/1000 fly with 99.9% certainty (14 and 7 days 99 & 90%) ➡ **Elimination**
- 99% after 1.5-2 years of continuous trapping by doubling or tripling the number of traps ➡ **Elimination**





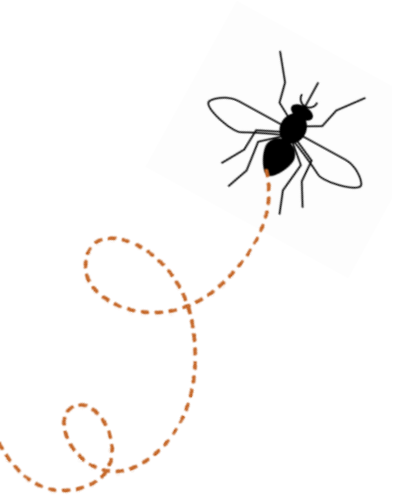
Step 5: Reinvasion risk

Distance is a barrier: The closest tsetse population is 50 km away

The Math: Given a 50km distance and a diffusion rate of 0.04km²/day, the time required for a fly to travel is significant. For $t \leq 100$ days, the probability is effectively zero of successful diffusion: $50/(0.04t)^{0.5} \geq 10 >> 0$ simplified to 0

The Conclusion:

- A fly can not complete the journey under 100 days
- Survival over more than 100 days is extremely unlikely
- Therefore, the risk of reinvasion from neighboring areas is vanishingly low



J. W. Hargrove, K. Lange, Tsetse dispersal viewed as a diffusion process. Trans. Zimb. Sci. Assoc. ***64****, 1–8 (1989).*

J. W. Hargrove, Tsetse Dispersal Reconsidered. J. Anim. Ecol. ***50****, 351–351 (1981).*

Conclusion: A new standard for demonstration of Elimination

Mandoul a success

Contribution to Tchad EPHP 2024

Tsetse population reduced to undetectable levels

Will be 99.9% confident of elimination in two years



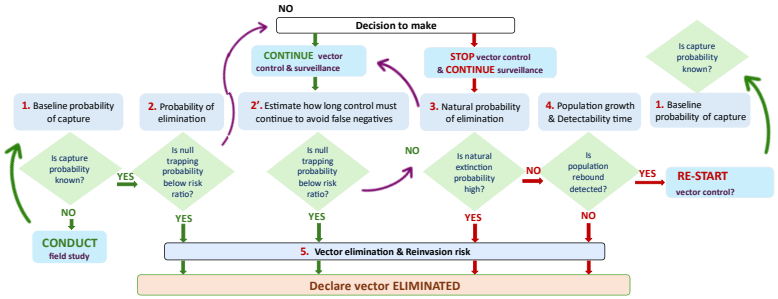
Zero!



Our framework

Our **multi-step framework** is a rigorous, evidence-based method to demonstrate elimination

It moves beyond a "wait and see" approach for vector control and elimination programs



The global impact

The method is **applicable to other vectors and diseases**, setting a new standard for disease elimination worldwide.

Acknowledgements

Dedicated to the memories of Hugh Barclay (1941 – 2022), who pioneered efforts to support the declaration of elimination of tsetse populations, of Jean-Baptiste Rayaisse (1967-2020) who was a fantastic tsetse entomologist, a hard worker, deeply committed to trypanosomiasis control, and with a great sense of humour, and to Ali Bachar Alkatib, killed by bees during the first target deployment in Mandoul.

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Thank you for your attention

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