

Controlling the Geographical Spread of the Tsetse Fly due to Global Warming

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Introduction

The Wildlife Conservation Society (WCS) in 2008¹ listed sleeping sickness as one of the “Deadly Dozen”: pathogens that may spread as a result of climatic changes. The tsetse fly is the vector responsible for the transmission of this disease also known as Human African trypanosomiasis (HAT). This review looks into the current geographical distribution of the tsetse fly, its climatic restrictions and the potential the tsetse fly has to spread with global warming and the measures which could prevent spread and the control measures.

Sleeping Sickness

Human African trypanosomiasis is a disease most commonly caused by the protozoan *Trypanosoma brucei* (Figure 1²), either the subspecies *T.b. gambiense*



Figure 1

Trypanosoma brucei species in a blood smear²

or *T.b. rhodesiense* which transmit West African and East African HAT respectively. The parasite is transmitted by the tsetse fly (genus *Glossina*)^{3,4,5}. These trypanosomes live in all body fluids and can be transmitted mother-to-child, via blood or through sexual contact⁶. HAT currently resides within 36 sub-Saharan African countries and mostly affects rural, poorer areas (due to frequent contact with animals) but also affects urban areas of endemic countries and travellers (Figure 2⁷).

Trypanosome Life Cycle

A tsetse fly will ingest trypomastigotes in an infected host's (human or animal) blood. Within the fly's gut and salivary glands trypomastigotes become infective. These are transferred to a new host during the fly's next blood meal, then undergoing binary fission, ready to be taken up by the next fly (Figure 3⁸). Once infected, the tsetse fly will remain infected until death⁸.

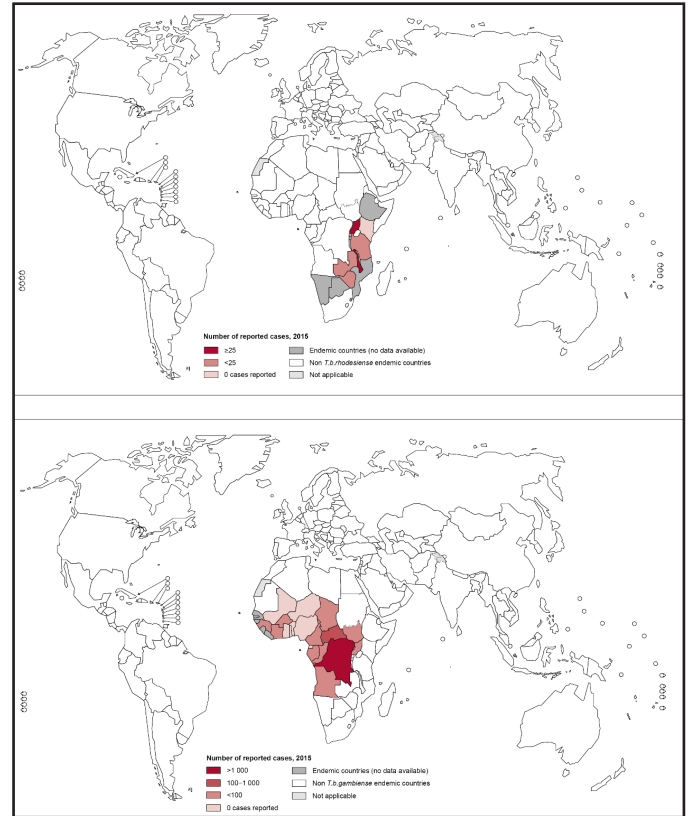


Figure 2

Distribution of HAT worldwide, in 2015, showing *T.b. gambiense* (above) and *T.b. rhodesiense* (below)⁷

Presentation

During the first, haemo-lymphatic stage patients can be asymptomatic or have unspecific symptoms. After the parasite crosses the blood-brain-barrier beginning the meningo-encephalic stage, symptoms include lethargy, disturbed circadian rhythm, coma and death. Duration of symptoms can differ depending on

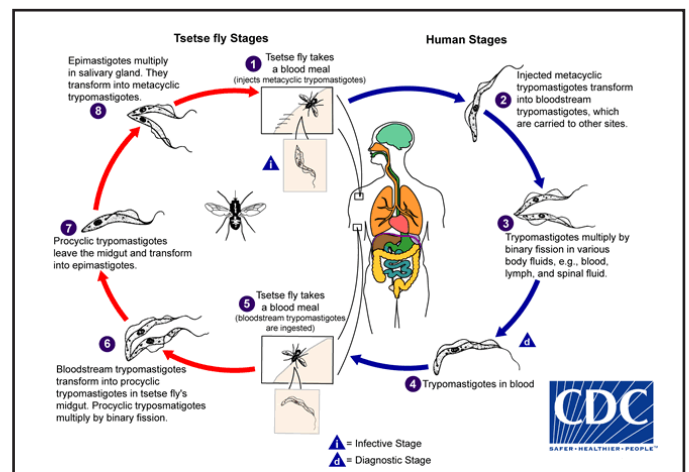


Figure 3

Human and tsetse fly stages of the trypanosome life cycle⁸

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the protozoan subspecies; *T.b. rhodesiense* infections are acute while *T.b. gambiense* infections are chronic^{3,9}.

Diagnosis

Early diagnosis of HAT can avoid disease progression and difficult treatments but, is difficult due to unspecific symptoms. Definitive diagnosis involves trypanosome detection in the blood (*T.b. rhodesiense*), lymph (*T.b. gambiense*)¹⁰ or cerebrospinal fluid (at the meningo-encephalic stage). Confirmation is made with a parasitological test but this has low sensitivity⁹. The WHO initiative - providing specimen banks for researchers - could develop new, less invasive tests with easy staging and a higher sensitivity allowing earlier detection^{6,11}.

Treatment

The treatment of HAT depends on the stage, the parasite and the skills of the health workers⁹. The haemo-lymphatic stage is treated with intramuscular pentamidine (*T.b. gambiense*) or intravenous suramin (*T.b. rhodesiense*). The meningo-encephalic stage is treated with eflornithine (*T.b. gambiense*), nifurtimox (*T.b. gambiense*), or melarsoprol (both). All drugs have many, sometimes toxic side effects^{6,12,13}. Nifurtimox-eflornithine combination therapy (NECT) is commonly used but is a complex regime requiring trained staff. Nifurtimox, currently supplied by the WHO in endemic countries, is orally administered and requires fewer resources^{3,6,13}.

Tsetse Fly

The tsetse fly is a member of the *Glossina* genus native to Africa. *G. palpalis* and *G. morsitans*, in particular, are essential in transmitting *T.b. gambiense* and *T.b. rhodesiense* respectively, from animals to humans and vice versa^{14,15}.

Habitat Distribution

Glossina species have a range of habitats and climatic restrictions¹⁶. The ideal temperature for the tsetse fly is between 25-26°C¹⁷ and deviation from 16°C-38°C (16°C-32°C for pupae survival) can result in inability to fly and eventual death. The ideal humidity is 50%-80% of relative humidity¹⁴. Tsetse flies are generally restricted between 14°N and 29°S. High temperatures and humidity in the north and south of Africa limit the fly's spread with cold winter months in the south inhibiting pupae development¹⁷.

The areas most suitable for the tsetse fly are places with shade/vegetation, savannah and freshwater swamps. Examples of areas unsuitable for *Glossina* to

thrive are cotton fields, herbaceous crops, flooded fields, urban areas, bare soil, lakes, rivers and grassland^{14,17}.

Vegetation provides shelter and shade for resting flies or developing pupae, but this habitat is altered by both humidity and temperature¹⁶. Rainfall can drown pupae but also increases humidity which allows the tsetse fly to spread from sheltered habitats like woodland, to more northern areas, such as Savannah. Breeding sites for pupae development are found in soil in animal holes, under logs or dense vegetation¹⁷.

The important factors impacting the distribution of tsetse flies are, therefore, temperature, vegetation, food source and humidity. It is important to note that microenvironments such as overhanging river banks, hollow trees and animal burrows allow the *Glossina* species to be found in less typical habitats despite less vegetation. Therefore, man-made microenvironments in villages such as plantations and farmland along riversides create the ideal cooler or more humid conditions for the tsetse flies to thrive^{14,16,17}.

Behaviour

Tsetse flies are daytime biters and spend a limited time in flight (15-30 minutes/day) avoiding the heat of mid-day. Resting sites are very important and tend to be tree trunks, undersides of logs or branches and in tree canopies during the cooler seasons^{14,17}.

Global Warming

It is recognised that although the tsetse fly currently resides within 36 sub-Saharan African countries⁶, environmental changes and animal movements could result in the spread of HAT^{1,7,14}. The spread of West Nile fever and Lyme disease have already illustrated the impact of climatic changes on insect disease vector migration. Despite short flying periods across short distances, tsetse flies have the potential to move several kilometres in several days (either passively on cattle and vehicles, or actively)¹⁴, so with climate change, spread may not only be possible but attractive to tsetse flies in search of optimal conditions.

Tsetse flies are dependent on wild animals for a blood meal, so a correlation exists between wild animal numbers and tsetse fly distribution. Animals could be a useful tool for predicting spread as suggested by the WCS. The WCS already monitors wild bird populations to follow avian influenza, allowing disease screening of predicted affected populations¹. With a warming climate, water availability in

drought-prone areas will reduce. If fewer water sources exist, more animal reservoirs (domesticated or wild) will congregate at one source, acting as an adjuvant for disease transmission, allowing sleeping sickness to spread to areas it wouldn't necessarily have reached previously¹⁷.

Scientists at the Centers for Disease Control (CDC) have predicted that tsetse fly distribution will change with temperature. They concluded that due to global warming tsetse flies will migrate south, where it was previously cooler, and larvae may not be able to survive in warming eastern areas. They predict that by 2090, the extent of the fly's temperature range will be 85-111% of its current size and a further 46-77 million people will be at risk of the disease¹⁸. However, tsetse flies also require the correct vegetation, rainfall and humidity¹⁷.

Figure 4¹⁹ shows predicted areas where *G. morsitans* and *G. palpalis* could thrive. Variables used to predict areas suitable for these Glossina subspecies were: vegetation, temperature and moisture as well as demographic, topographic and agricultural patterns¹⁹.

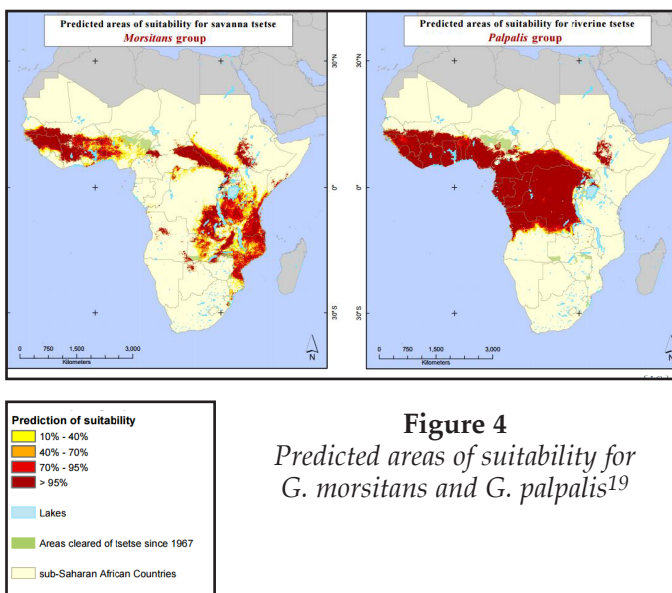


Figure 4
Predicted areas of suitability for
G. morsitans and *G. palpalis*¹⁹

Although spread from sub-Saharan Africa could occur, this may be a shift in distribution rather than an increase in range. Predictions in spread and distribution could be crucial in implanting screening and control measures followed by, hopefully, the eradication of the disease.

Prevention and Control

Due to HAT mostly affecting rural sub-Saharan Africa, distribution of aid, control and surveillance is

difficult. Three epidemics occurred over the last century⁶ due to relaxation of control efforts which were reducing the prevalence of sleeping sickness¹⁴. Eradication should involve a sustained effort with multiple prevention and control schemes. The WHO decided in 2012 to attempt to eradicate sleeping sickness and their objectives are described briefly in Table 1⁶.

New drugs are needed that are safe, don't require skilled health workers, are less toxic and treat both forms of infection. Currently, pafuramidine is in development, is administered orally, which could be less toxic than pentamidine^{11,14,20,21}.

• Strengthen surveillance
• Provide accessible diagnosis and treatment
• Monitor treatment and drug resistance
• Develop a database for epidemiology
• Train all staff
• Support research on new diagnoses and treatments
• Maintain control measures, avoiding resurgence
• Use irradiation of male flies for vector control
• Collaborate with PATTEC

Table 1
Objectives of the WHO eradication programme⁶

The WHO is planning population screenings followed by a check-up after 2 years²². Hopefully, along with identification of uncontrolled endemic foci, resurgence will be prevented. Card Agglutination Trypanosomiasis Test (CATT) is a serological screen determining the presence of T.b. gambiense only, but is useful in populations where that form is prevalent e.g. western and central Africa⁹.

Microenvironments and resting sites are important to consider in spraying programmes¹⁷. Insecticides such as DDT¹⁴ should be used in dense vegetation and breeding sites but also in microenvironments. Other vector controls are being implemented by the WHO in association with Pan African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC), despite being costly on a large scale²². In 2001 PATTEC used odour-baited traps, insecticide-treated targets, sterile male technique and insecticide spraying to reduce tsetse fly population¹¹. The sterile male technique seems promising in Zanzibar and Senegal, after tsetse fly numbers were first reduced by

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conventional methods. Trap monitoring showed a reduction in the number of flies post sterilisation²³.

Another difficulty with eradicating HAT is the infection of both animals and humans. Rinderpest disease killed off many African animals in the late 19th century resulting in a reduction in tsetse fly numbers¹⁷. Controlling these reservoirs of infection (wild animals and livestock) is essential. Many African cattle have trypanosomiasis resistance but those imported from Europe are highly susceptible to trypanosome infection. However some areas show non-African breeds developing a tolerance as a result of local evolutionary adaptations²⁴. Hopefully an integrated approach involving veterinary services could aid in controlling reservoirs of infection¹⁴.

Both locals and travellers should be educated over their individual risk of being infected. For example, the route of infection, precautions to take in tsetse fly habitats¹⁴ e.g. wearing appropriate clothing (long, khaki or olive-coloured clothing), the use of insect repellents, bed nettings and screens.

Conclusion

As the vector of HAT, the tsetse fly has a huge potential to affect disease spread. With climate change, their distribution is likely to change as temperatures rise and water availability reduces. Therefore the importance of tracking climatic changes will be essential in predicting the spread of the tsetse fly, and with it sleeping sickness.

Currently, there is no vaccine against HAT but this could be the key to final eradication. Vaccine development is ongoing but there are several obstacles including antigenic variation and problems with using murine models (e.g. destruction of immunological memory)²⁵. Hopefully a different model can be used that more accurately reflects the host-parasite interactions.

The WHO reported that blood vats were used by the people of Sudan to bait tsetse flies away from their cattle²⁶. However this method was not described again as a possible vector control. This could be used to bait tsetse flies to sprayed areas or used by locals to protect their cattle. Tsetse flies are known to be affected by parasites and pests. However there was no mention of whether these could be used as a specific vector control method¹⁷.

An alternative screening test to CATT needs to be developed that can detect *T.b. rhodesiense*. Also, the development of new drugs to remove toxic side

effects and provide an easier route of administration is needed if the eradication of HAT is to be achieved.

It is unclear in which countries the WHO's scheme for eradication will be implemented, or whether they are considering the spread of the tsetse fly with climate change. A pool of countries, not yet affected by sleeping sickness, could be considered and may require screening. This is especially important if the disease is not immediately apparent within a population.

If the tsetse fly can be tracked via animals or disease trends then at-risk individuals can be treated before the disease progresses and control can be maintained. The most important aspect of prevention is the combination of active case detection and control of spread²¹ and hopefully if a vaccine can be created, eradication will be a real possibility.

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