Host Searching Behavior of Malaria Mosquitoes in a Turbulent Airflow

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Introduction

The mosquito is one of the deadliest animals in the world. It is responsible for the spread of many deadly diseases such as malaria, zika, dengue, chikungunya and West-Nile virus. In 2020, malaria deaths were estimated to be 627,000 and 77% of these were children (World malaria report (2021)).

To find a human host, flying malaria mosquitoes track a human odor plume using a so-called cast-and-surge flight behavior (Figure 1; van Breugel et al. 2015; McMeniman et al. 2014). It is curerently not known how turbulence affects this host-searching behaviour.

Here, we hypothesize that in high turbulence conditions, mosquitoes need to perform casting more frequent, and therefore approach a human host more slowly (Figure 1). We experimentally test this hypothesis by tracking host searching malaria mosquitoes in both low and high turbulent airflow conditions.

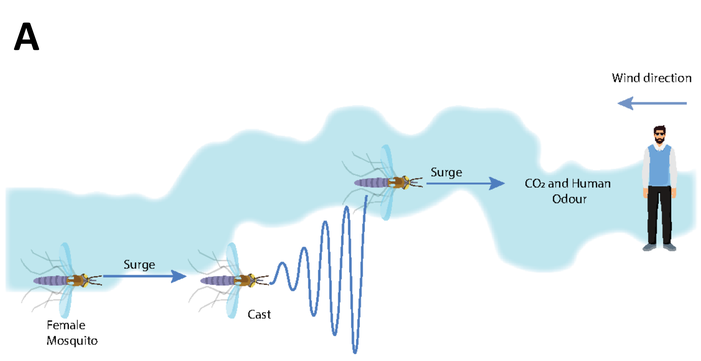

Figure 1: Hypothesized cast-and-surge flight behavior of host-searching malaria mosquitoes in (A) low turbulent airflow and (B) high turbulence. (A) At low turbulence, mosquito are hypothesized to perform fewer casting maneuvers and longer surges, thereby travelling faster upwind.

Materials and Method

We have developed a mosquito-flight wind tunnel producing turbulent airflow, and a stereoscopic videography system for tracking the flying mosquitoes host-searching in low and high turbulence. (fig. 1). We study host-searching behavior of malaria mosquitoes under both low and high turbulent conditions.

Experiments with malaria mosquitoes were conducted in a wind tunnel of 160 cm in length and 60x60 cm cross section (Figure 2) at velocities of 20 cm/s. We used a fractal grid system to produce increased air turbulence in the tunnel (Figure 3).

3D tracking of the malaria mosquitoes was done by a real time DLT tracking system (Spitzen et al. (2013)).

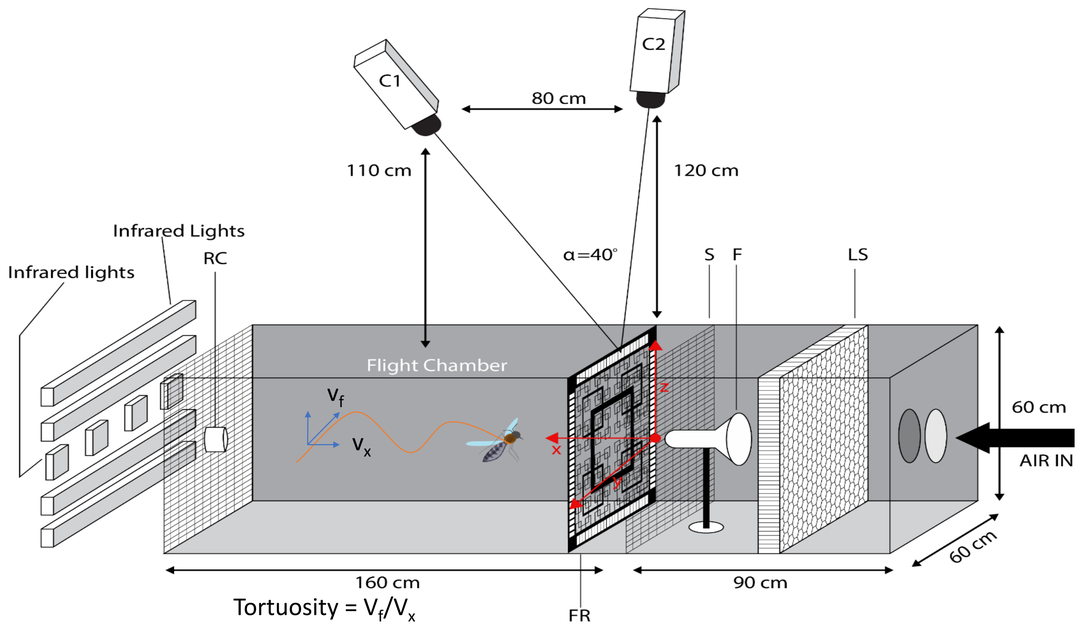

Figure 2: The experimental wind tunnel setup. Mosquitoes are released at the release chamber (RC) . They then fly towards the odor source released from the funnel (F).

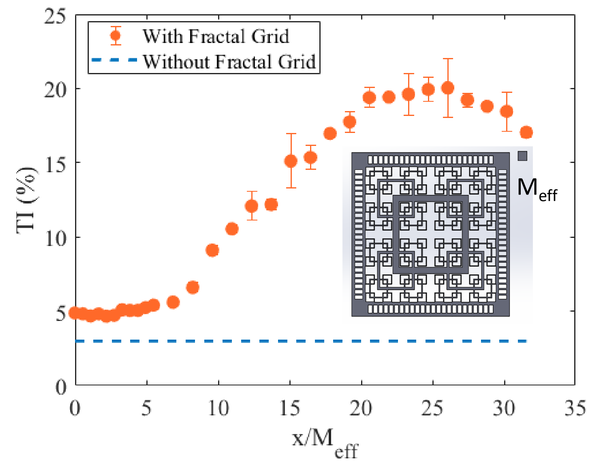

Figure 3: Turbulence intensity (TI) development along the longitudinal direction of wind tunnel, with fractal grid (orange) and without (TI=3%, blue).

Results

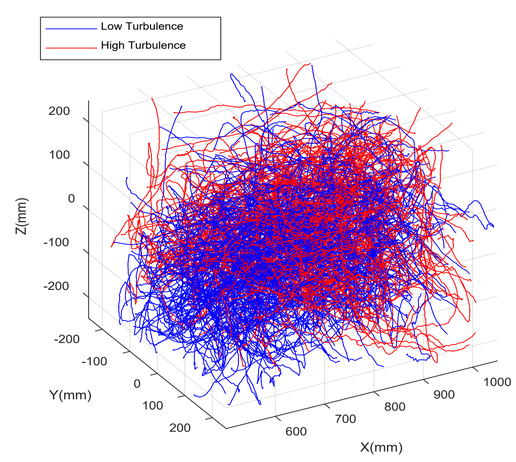

Figure 4: A range of recorded flight tracks of host-searching mosquitoes flying in low and high turbulence conditions (in blue and red, respectively).

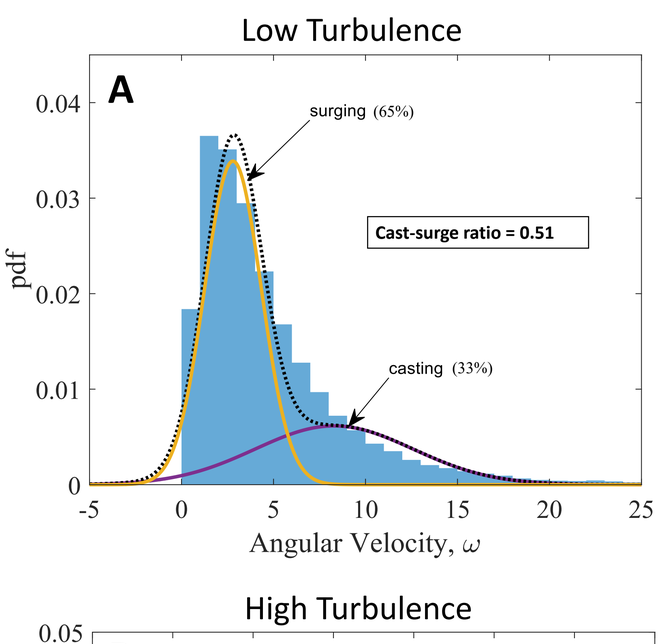

Figure 8: We estimated the cast-to-surge ratio using a gaussian mixed model applied to the angular flight velocity distributions. Here, we assume that at high angular velocities mosquitoes are casting, and at low angular velocities they are surging (van Breugel et al 2014). This shows that in high turbulence airflow, mosquitoes cast relatively 10% more often than in low turbulence.

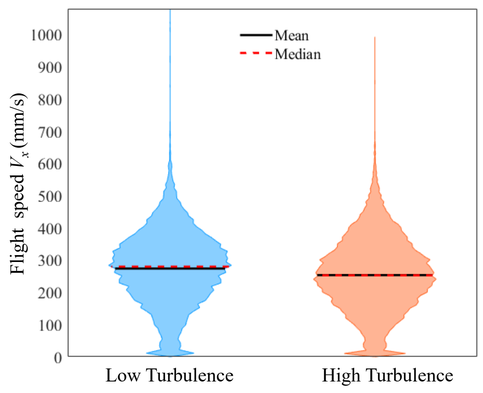

Figure 5: The flight speed V_f of host-searching mosquitoes in high turbulent airflow (red) is on average 10% lower than of those in low turbulent airflow (blue) (*t*-test, *p*-value <0.001).

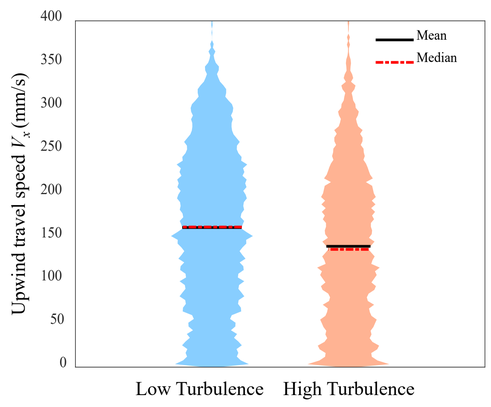

Figure 6: The upwind travel speed V_x of mosquitoes host-searching in high turbulence (red) is on average 15% lower than of those in low turbulent airflow (blue) (*t*-test, *p*-value <0.001).

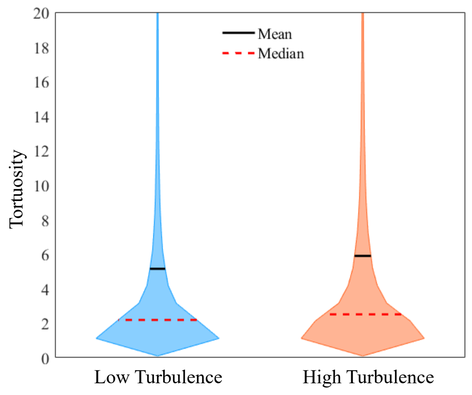

Figure 7: The flight tortuosity, being the ratio between flight speed and upwind travel speed (Figure 2), is on average 14% higher for mosquitoes host-searching in high turbulence (red) than in low turbulence airflow (blue) (*t*-test, *p*-value <0.001).

Conclusions

- Fractal grid produces appropriate turbulence levels for studying mosquito host-searching.
- Mosquitoes were able to host-search in both low and high turbulence conditions.
- Mosquitoes host-searching in high turbulence fly and travel upstream at lower speeds as those in low turbulence (Figures 5 and 6).
- At high turbulence, mosquitoes fly at 14% higher tortuosity levels than in low turbulence.
- Mosquitoes host-searching in high turbulence perform relatively 10% more casting maneuvers than mosquitoes host-searching in low turbulence; this confirms our hypothesis (Figure 1).
- Host-searching malaria mosquitoes precisely adjust their cast-and-surge flight behavior such that they minimize the detrimental effect of turbulence on host-searching performance.

Contact

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