Mimicking Atmospheric Flow Conditions to Examine Mosquito Orientation Behavior

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1 Introduction

Mosquitoes are known vectors for many infectious diseases, including malaria and West Nile virus. One of the most notorious species is *Aedes aegypti*, also known as the yellow fever mosquito, which in addition to its namesake also carries other diseases including dengue fever and chikungunya. Recently, the species has been the focus of intense interest due to the role females *A. aegypti* play in the transmission of the Zika virus. Such new mosquito-borne diseases have been increasing in number due to anthropogenic disturbances and climate change, and in the face of this challenge, the host-seeking behavior of female mosquitoes is viewed as a target for disruption in the disease transmission cycle. Thus, experiments that expand our understanding of the orientation strategies used by mosquitoes may lead to drastic improvements in mosquito control.

Much of the work which has been performed on mosquito orientation has involved field and laboratory bioassay methodologies, including suction trapping (field), landing on humans/traps in large semi-field cages, entrance of flying mosquitoes into a trap or port, hand-in-box assays, and close-range orientation assays [1, 2, 6, 7, 8]. While these studies have produced valuable information regarding effective cues, the flow conditions in these studies are not always reported and/or well-characterized, placing limits on our understanding of the influence of atmospheric flow conditions upon mosquito orientation behavior.

In order to better simulate odor dispersion and plume structures encountered by mosquitoes in natural settings, wind tunnel tests are often employed [4]. However, previous work utilized either laminar flows — which lack the fluctuations and multi-scale characteristic of the highly turbulent atmospheric boundary layer — or turbulent flows generated by passive grids — which generate only small scale turbulent fluctuations [3]. Even if the grid-generated turbulence matches the turbulence intensities found in mosquitoes' natural habitats, the time and length scale effects of larger and slower flow features on the scalar dynamics have essentially been ignored. Further, as evidenced by unique orientation behaviors that are observed only in lab settings, studies suggest that the host-finding behavior of mosquitoes is affected not only by the odor composition but also by the characteristics of the flow environment [5].

2 Research Conducted Thus Far

In order to bridge between laboratory findings and the natural, ecologically relevant setting, an active grid was developed to impose a wide range of flow length and time scales representative of the features of the atmospheric boundary layer, where mosquitoes inhabit. The active grid consists of 67 independently-controlled paddles that are arrayed on a 2' by 3' rectangular frame. Each square paddle rotates about its own diagonal and is able to move 90° in either direction from the open position. The paddles' positions are controlled through TCP/IP protocols sent from a computer to the servos' wireless micro-controllers, with the speed of movement limited mostly by the servos' operating speed of 0.12 s/60°. The active grid's high number of degrees of freedom results in considerable control over the turbulence generated behind it. By modifying the amplitude and the velocity of the paddles, various flow structures may be imposed downstream of the active grid. With the correct prescribed active grid protocols, the flow features inside the wind tunnel can mimic that of natural, field conditions. Under these relevant settings, experiments can be performed regarding the evolution of the dynamics of scalar cues, and consequently the host-seeking response of disease-carrying mosquitoes. The active grid is to be deployed in a low-speed smoke tunnel in the Gas Dynamics Laboratory at Forrestal. The tunnel is a 5 m long, 1.2 m by 0.9 m in cross-section, open-return wind tunnel with freestream velocities between 0.8 and 2.5 m/s. This range of speeds is consistent with those encountered by mosquitoes in real life. In a preliminary flow visualization experiment, the tunnel was operated at about 1 m/s and incense was lighted 1 m downstream of the active grid. It could be seen that when each paddle was programmed to carry out a slow, sine-wave motion synchronously, the resulting flow field contained periodic large-scale motions that corresponded to the paddle movements. This serves as proof of concept for the active grid's efficacy in creating the varying length and time scales found in the atmospheric boundary layer.

3 Future Work

The logical and crucial next step is to obtain a detailed characterization of the grid-generated flow — namely the turbulent velocity field — in order to accurately calculate the correlations and integral length scales. These characterizations are instrumental in determining the relationship between the paddles' convolution functions and the resulting turbulent flow; in other words, given a desired flow feature, this provides a guide for the prescribed paddle motion that is needed. Once the active grid's correlating forcing abilities are well characterized, the flow features can then be matched to that of the atmospheric boundary layer. Under such an ecologically-relevant setting, scalar transport can be studied with temperature as the scalar using an array of nano-scale temperature sensors (T-NSTAPs). Finally, the active grid will be deployed in a similar wind tunnel in the University of Utah, where mosquito orientation behavior can be studied under the supervision of Professor Neil Vickers in the Department of Biology.

Overall, this research serves to provides a comprehensive exploration and understanding of the dynamics of a scalar plume as it evolves, which not only establishes the effect of fluid environment on the scalar coherence and distribution, but also provides a bioassay platform for approaches directed at disrupting or preventing the cycle of mosquito-vectored disease transmission.

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