Experimental Study of Tabanid Polarotaxis, Host-Tabanid Interaction and Polarization Tabanid Traps

Summary of Ph.D. Thesis

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1. Introduction

Tabanid flies occur in all continents except for Antarctica. While they are pollinators of numerous plants and there are several predators which feed on them, they represent threat to a number of mammals, especially grazing ungulates, since they are vectors of dangerous diseases. Hence, there is a large need to reduce the number of tabanids on horse and cattle farms. Different tabanid traps are available on the market, which are more or less effective and capture almost exclusively female tabanid flies.

Tabanid flies are attracted to horizontally polarized light as several other aquatic insects. One of my goals was to study experimentally the attraction of tabanids to linearly polarized light, and to develop new, more effective tabanid traps exploiting the recently demonstrated positively polarotactic behaviour of tabanids. This led to the discovery of a new kind of polarotaxis, which is present in host-seeking female tabanid flies.

The new concept of polarized light pollution has been introduced a few years ago, and it has been shown that shiny dark artificial surfaces (e.g., solar panels) can reflect highly polarized light and deceive water-seeking polarotactic aquatic insects. These insects tend to land and oviposit on these polarizing surfaces, which leads to the failure of their reproduction. I suggested a general method to reduce the polarized light pollution induced by man-made surfaces.

The same method of reducing polarized light pollution has been evolved by zebras in nature. Zebras are one of the most exotic animals thanks to their mysterious striped coat pattern. I proposed a new, experimentally supported explanation for the evolutionary advantage of zebra stripes by showing that striped patterns are beneficial against blood-sucking polarotactic tabanids.

2. Materials and Methods

In my Ph.D. thesis I present the results of several field experiments, in which I studied the polarotactic behaviour of certain aquatic insects, mainly tabanid flies. I measured the reflection-polarization characteristics of test surfaces and tabanid traps used in these field experiments by imaging polarimetry in the red (650 ± 40 nm = wavelength of maximal sensitivity ± half bandwidth of the CCD detectors of the polarimeter), green
(550 ± 40 nm) and blue (450 ± 40 nm) parts of the spectrum. These polarization patterns were very similar in all three spectral ranges, because the test surfaces, visual targets, tabanid traps and zebra coats were colourless (black, grey, or white).

The taxonomic identification of tabanids trapped by canopy traps and liquid traps was performed by co-authors (tabanid experts: Mónika Gyurkovszky, Prof. Róbert Farkas, Prof. József Majer). When the trapped tabanids were removed from the insect monitoring sticky surfaces, their body suffered so serious damage that their taxonomical identification was impossible. They were, however, unambiguously identified as tabanid flies (Diptera: Tabanidae). During experiments when only sticky surfaces were installed at a given site, we captured tabanids parallelly with a trap composed of a black plastic tray (50 cm × 50 cm) filled with a transparent vegetable oil, thus we could monitor the tabanid species in the vicinity. The tabanid flies captured in the field experiments without body damages were conserved in ethyl alcohol and their sex and species were identified later in the laboratory.

The most important outputs of the field experiments were the total numbers of tabanids captured by the different traps, test surfaces and targets. The trapped tabanids were counted periodically and frequently (daily or weekly, depending on the weather and the test situation). Since the experiments often lasted for a whole summer (three months), the traps and test surfaces/targets needed cleaning and removal of the captured non-tabanid insects in order to eliminate the visual noise. On the other hand, the sticky glue used in many experiments tended to lose its efficiency after a few weeks, thus it must have been refreshed. Therefore, the tabanid flies were counted frequently in each experiment. Nevertheless, the most relevant information was their total catches. To obtain the significance of differences between these total tabanid catches, it was enough and appropriate to use the binomial $\chi^2$ test almost in all situations.
3. Results

3.1. New Kind of Polarotaxis Governed by the Degree of Polarization: Attraction of Tabanid Flies to Differently Polarizing Host Animals and Water Surfaces

(3.1.1.) I showed that female tabanids possess a new kind of polarotaxis, which is governed by the degree of linear polarization, rather than the direction of polarization of reflected light.

(3.1.2.) I demonstrated that the host choice of blood-sucking female tabanids is partly governed by the linear polarization of light reflected from the host’s coat.

(3.1.3.) I explained the enigmatic attractiveness to tabanid flies of the shiny black sphere used in traditional canopy traps.

3.2. A New Tabanid Trap Applying a Modified Concept of the Old Flypaper: Linearly Polarizing Sticky Black Surfaces as an Effective Tool to Catch Polarotactic Tabanid Flies

(3.2.1.) I designed a new sticky tabanid trap consisting of a horizontal and a vertical part. I conducted field experiments to determine the optimal colour, size and altitude of this two-component trap.

(3.2.2.) I found that this tabanid trap must be black, the ideal altitude of the horizontal and vertical parts are 0 and 1 meter above the ground level, respectively, and the ideal size of both parts is 75 cm × 75 cm.

(3.2.3.) I introduced a prototype of the new sticky tabanid trap. I demonstrated that its horizontal part attracts water-seeking male and female tabanids, while its vertical compartment lures host-seeking female tabanids, contrary to the classic canopy traps capturing only host-seeking female tabanids.
3.3. Enhancing the Tabanid-capturing Efficiency of the Classic Canopy Trap with a Horizontally Polarizing Liquid Trap

(3.3.1.) I designed a new, effective, weather-proof, liquid-filled tabanid trap, which perfectly imitates the reflection-polarization characteristics of water surfaces, and thus attracts water-seeking male and female polarotactic tabanids.

(3.3.2.) I showed that horizontally polarizing surfaces must be located on the ground in order to attract efficiently tabanid flies. Thus the ideal altitude of the novel liquid-filled trap is the ground level.

(3.3.3.) I demonstrated that the new liquid trap can considerably enhance the effectiveness of the traditional canopy trap being most effective against host-seeking female tabanids.

(3.3.4.) I showed that the liquid trap is more efficient than the canopy trap, thus it can be used as a stand-alone tabanid trap.

3.4. Reducing the Maladaptive Attractiveness of Solar Panels to Polarotactic Insects

(3.4.1.) I presented a new method for reducing the polarized light pollution induced by artificial surfaces, especially solar panels (collectors and photovoltaic cells).

(3.4.2.) I showed that a dense enough white grid pattern drastically reduces the attractiveness of highly and horizontally polarizing artificial surfaces to polarotactic aquatic insects.

(3.4.3.) I demonstrated that placing an appropriate white grid on a solar panel significantly reduces the attractiveness of the panel to polarotactic insects, while the loss of energy production is less than 2%.
3.5. Polarotactic Tabanids Find Striped Patterns with Brightness and/or Polarization Grating Least Attractive: An Advantage of Zebra Stripes

(3.5.1.) I proposed a new explanation of the evolutionary benefit of zebra stripes. The results of six field experiments provided strong experimental support for this proposal.

(3.5.2.) I demonstrated that zebra-striped two-dimensional surfaces and three-dimensional zebra models attract far fewer tabanids than either homogeneous black, brown, grey or white equivalents.

(3.5.3.) I showed that the attractiveness of black-and-white striped targets to tabanid flies decreases with decreasing stripe width. I demonstrated that the stripe widths of real zebras fall in a range, where the striped pattern is most disruptive to tabanids.

(3.5.4.) I showed that homogeneous dark grey horizontal and vertical surfaces with stripes of alternating orthogonal directions of polarization are also less attractive to polarotactic tabanids than similar surfaces with homogeneous direction of polarization.
4. Publications

4.1. Publications Representing the Basis of the Ph.D. Thesis


4.2. Additional Publications Relating to the Ph.D. Thesis


