Ecological and Physiological Studies of Complex Ecological Traps and Zebra-Striped Skin Surfaces

Summary of Ph.D. thesis

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1 Introduction

In the first three chapters of my doctoral thesis I present my studies about ecological traps induced by polarized light pollution. Ecological traps are behavioural phenomena where individuals of a population follow an earlier adaptive behavioural pattern after a rapid environmental change and choose inappropriate habitats to themselves or to their offspring. This leads to the reduction or extinction of the population. Polarized light pollution is an example of ecological traps that threatens mostly aquatic insects. Typical polarized-light polluting sources are those artificial surfaces which reflect highly (high degree of polarization) and horizontally polarized light. When an aquatic insect has to choose between such an artificial surface and water, it selects the former because the highly and horizontally polarized reflected light is a supernormal optical stimulus for polarotactic insects. The artificial polarized light polluting surfaces appeared and spread very fast in evolutionary scale, thus aquatic insects had no time to adapt to the changed optical environment. Because of polarized light pollution the formerly adaptive water-seeking strategies that are based on detection of horizontally polarized light reflected by water became maladaptive where polarized light pollutants were abundant.

During their compensatory flight female mayflies intend to fly above the water surface which reflects horizontally polarized light. If *Ephemera danica* (Müller, 1764) mayflies loose the horizontally polarized signal they fly high to find their way back to water. If an asphalt road covered bridge is close to the water surface then mayflies emerge above the road. The horizontally polarized light reflected by the road deceives mayflies so they continue their compensatory flight above the road. *Ephemera danica* mayflies following the road may get distant from the creek while continuing their compensatory flight until they find a stronger polarized-light polluting surface which can trigger oviposition. Such surface can be a puddle in the road for example. We examined this ecological trap for *Ephemera danica* mayflies in field experiments.

The compensatory flight of night swarming *Ephoron virgo* (Olivier, 1791) mayfly females is also disrupted by bridges above the river. When mayflies arrive to a bridge during the compensatory flight, their positive phototaxis brings them to the bridge lights and to the street lamps. Later, as the mayflies get exhausted, they lay their eggs on the horizontally polarizing asphalt road instead of the river which will dry and perish. We hypothesized that unpolarized beacon lights above the river surface can prevent egg-laying female mayflies to leave the river, hence guarantee to ovipositioning into the river. In field experiments at rivers Ipoly and Rába we tested prototype beacons and studied whether they can keep mayflies above the river.

In every April and May, swarming *Hydropsyche pellucidula* (Curtis, 1834) caddisflies appear around glass buildings at the riverside of the river Danube in Budapest. These caddisflies swarm in front of the buildings and rest on them in large numbers during the daytime. Since the cover of the buildings provide weak shelter, the large mass of the swarming caddisflies is an easily exploitable food source for several bird species. Previously four bird species have been observed to feed on caddisflies at glass buildings. I observed great spotted woodpecker (*Dendrocopos major* Linnaeus, 1758), black redstart (*Phoenicurus ochruros* Gmelin, 1774) and hooded crow (*Corvus cornix* Linnaeus, 1758) feeding on *H. pellucidula* caddisflies.

In the second part of my PhD thesis, I present our field experiments studying some ecological and physiological impacts of zebra-striped surfaces. As many as 18 different explanations have been proposed for the possible functions of zebra stripes which can be combined into the following four major groups:

1. anti-predation, including camouflage and various aspects of visual confusion,
2. facilitating social interactions,
3. thwarting the attack of biting flies, and
4. regulating body temperature.

Hypothesis 3 has been experimentally tested and corroborated by field observations and experiments. These studies examined the attraction of horseflies (Tabanidae) and tsetse flies (Glossinidae) to their four-legged hosts. Members of certain aboriginal communities paint bright stripes on their dark brown body skin. Many body decoration motifs resemble to zebra stripes. The elongated semi-cylindrical shape of the human body differs considerably from the shape of the quadrupedal hosts of horseflies, thus the results from previous field studies cannot be applied automatically to the reaction of horseflies to striped bodypainting. We hypothesized that similarly to zebra stripes the striped bodypainting significantly decreases the number of horsefly attacks. To test this hypothesis we examined horsefly attraction of differently coloured and patterned human models.

According to Hypothesis 4, zebra stripes are expected to cool the body by means of convective air eddies induced by temperature gradients over alternating black and white stripes. This hypothesis has been studied previously with thermography and correlations between temperature variability and changes in striping of equid species and subspecies. We tested this hypothesis in field experiments in which we measured the core temperatures of water-filled metal barrels covered with differently coloured and patterned hides.

2 Aims and Objectives

In my doctoral thesis I answer the following questions:

- Can the offspring generation of *Ephemera danica* mayflies be saved which are deceived by the weakly and horizontally polarized light of the asphalt road from the creek?

- Can the mass devastation of *Ephoron virgo* mayflies be prevented at bridges using downstream-facing artificial lights mounted to the bridges?
- What bird species are capable to utilise the food source made of swarming *H. pellucidula* caddisflies at the riverside of the river Danube?
- Does the striped bodypainting used by aboriginal tribes reduce the number of horsefly attacks?
- Do zebra stripes cool the animal?

Furthermore, I show possible remedies to the following environmental problems:

- How to save the offspring generation of certain stream-living mayflies by deploying horizontally polarized light reflecting water-filled traps?
- How to protect the offspring generation of *Ephoron virgo* mayflies at illuminated bridges?

3 Materials and Methods

3.1 The complex ecological trap for *Ephemera danica* mayflies

We examined the behaviour of *Ephemera danica* mayflies at a bridge crossing a creek. In the experiments we deployed horizontally polarizing insect traps (oil-filled black trays and shiny black and red surfaces) in various arrangements. The number of observed landings, catch of oil-filled trays and clutches were analysed with χ^2 homogeneity test. The reflection-polarization characteristics of the traps and the asphalt road was measured in the red (650 nm), green (550 nm) and blue (450 nm) spectral ranges by imaging polarimetry.

3.2 Improving the survival of *Ephoron virgo* mayflies near illuminated bridges

We tested beacon lights developed to protect female *Ephoron virgo* mayflies in two sites at rivers Ipoly and Rába. We took pictures using two DSLR cameras of the two street lamps being closest to the bridge at a rate of approximately three images per minute per camera. This way we could estimate how many mayflies left the river. During the swarming we switched off the beacons three times for 3–6 minutes in order to prove that the mayflies leave the river and get trapped at the street lamps in huge numbers only when the beacons were switched off. The photographs of the street lamps were evaluated by counting the attracted mayflies on the images manually.

3.3 Atypical feeding of bird species at glass buildings at the riverside of Danube

We made visual observations at the northern building of the Faculty of Natural Sciences of the Eötvös University in Budapest, Hungary which were documented with photographs. Each time, when birds appeared or flew away, photos were taken. The points of time of these events were extracted from the exif data of the photos.

3.4 Striped bodypainting protects against horseflies

The field experiments were performed at a meadow near Szokolya, Hungary. We used homogeneous dark brown, dark brown with white stripes and homogeneous light beige plastic human models. The white stripes produced with a common oil paint on one of the brown models mimicked the stripes of African and Australian tribal bodypaintings. After the paint dried we covered the models with a thin, transparent, colourless, and weatherproof adhesive. The field experiments were performed for almost two months. During this period we collected the horseflies trapped by the sticky human models every second day. We applied factorial ANOVA with Tukey HSD post-hoc test to analyse the results. The reflection-polarization patterns of the models were measured with imaging polarimetry in the red (650 nm), green (550 nm) and blue (450 nm) parts of the spectrum.

3.5 Zebra stripes do not cool the animal

We conducted four field experiments in a horse farm at Göd, Hungary and examined if zebra stripes have traceable cooling effect for the water-filled metal barrels. The barrels were covered with differently coloured and patterned hides. The core temperature of the barrels was measured in every 5 minutes. Using thermography we registered the surface temperature of the sunlit barrels and living zebras, and measured the reflection spectra of the barrels and calculated their whiteness. An automatic meteorological station was installed beside the barrels that continuously measured the air temperature and the wind speed. Self-developed software was used to evaluate the measured data and for the statistical analysis ANOVA and Wilcoxon signed-rank tests were applied.

4 Results

4.1 The complex ecological trap for *Ephemera danica* mayflies

- I found that bridges can deceive *Ephemera danica* mayflies from the creek. Female mayflies continued their compensatory flight above the asphalt road.

- I proved that the mayflies leave the creek at the bridge and since they could not determine the direction of water flow they continued their compensatory flight in both directions along the road.
- I showed that the offspring generation of the deceived mayflies can be saved with black or red water-filled trays deployed along the edge of the road.

4.2 Improving the survival of *Ephoron virgo* mayflies near illuminated bridges

- I proved that beacons can prevent *Ephoron virgo* mayflies from leaving the river.
- I showed that using the beacons the mass devastation of night-swarming mayflies can be avoided.

4.3 Atypical feeding of bird species at glass buildings at the riverside of Danube

- I observed great spotted woodpecker (*Dendrocopos major* Linnaeus, 1758), black redstart (*Phoenicurus ochruros* Gmelin, 1774) and hooded crow (*Corvus cornix* Linnaeus, 1758) feeding on *H. pellucidula* caddisflies.
- I described the feeding behaviour of these bird species.

4.4 Striped bodypainting protects against horseflies

- I presented that standing human models reflect mostly vertically polarized light, while the reflected light from the lying ones is mainly horizontally polarized.
- I showed that the polarization pattern of the models explains why the standing models attracted only host-seeking female horseflies, while the lying models were visited by water-seeking male and female horseflies.
- The striped human model attracted less horseflies than the homogeneous brown or beige models. This proved the hypothesis that the traditional striped bodypainting used by indigenous tribal communities protects against horsefly attack as zebra stripes do.

4.5 Zebra stripes do not cool the animal

- I demonstrated that the measured differences in the barrels' core temperatures can be explained by the whiteness of the hides covering the barrels: the lower the average whiteness of the hide the warmer the barrel's core temperature.

- I showed that the core temperature of the barrels covered with striped hides (real zebra hide and artificial zebra hide sewed from stripes of black and white cattle hides) did not differ from the temperature expected on the basis of the hide's whiteness.
- The hypothetical cooling effect of zebra stripes was not detectable in our measurements, even when the data were restricted to periods with higher air temperatures and smaller wind speeds.
- In field experiments I disproved the thermoregulation hypothesis. Zebra stripes do not cool the animal.

5 Publications

5.1 Publications that formed the basis of the Ph.D. thesis

1. Á. Egri, **Á. Pereszlényi**, A. Farkas, G. Horváth, K. Penszka, G. Kriska (2017) How can asphalt roads extend the range of in situ polarized light pollution? A complex ecological trap of *Ephemera danica* and a possible remedy. *Journal of Insect Behavior* 30(4), pp. 374–384.
2. Á. Egri, D. Száz, A. Farkas, **Á. Pereszlényi**, G. Horváth, G. Kriska (2017) Method to improve the survival of night-swarming mayflies near bridges in areas of distracting light pollution. *Royal Society Open Science* 4, p. 171166.
3. **Á. Pereszlényi**, G. Horváth, G. Kriska (2017) Atypical feeding of woodpeckers, crows and redstarts on mass-swarming *Hydropsyche pellucidula* caddisflies attracted to glass panes. *Urban Ecosystems* 20(6), pp. 1203–1207.
4. G. Horváth, **Á. Pereszlényi**, S. Åkesson, G. Kriska (2019) Striped body-painting protects against horseflies. *Royal Society Open Science* 6, p. 181325.
5. G. Horváth, **Á. Pereszlényi**, D. Száz, A. Barta, I. M. Jánosi, B. Gerics, S. Åkesson (2018) Experimental evidence that stripes do not cool zebras. *Scientific Reports* 8, p. 9351.

5.2 Additional publications related to the Ph.D. thesis

1. G. HORVÁTH, T. SZÖRÉNYI, **Á. PERESZLÉNYI**, B. GERICS, R. HEGEDÜS, A. BARTA, S. ÅKESSON (2017) Why do horseflies need polarization vision for host detection? Polarization helps tabanid flies to select sunlit dark host animals from the dark patches of the visual environment. *Royal Society Open Science* 4, p. 170735.
2. G. HORVÁTH, **Á. PERESZLÉNYI**, T. TÓTH, S. POLGÁR, I. M. JÁNOSI (2019) Attractiveness of thermally different uniformly black targets to horseflies: *Tabanus tergestinus* prefers sunlit warm shiny dark targets. *Royal Society Open Science* 6, p. 191119.
3. Á. EGRI, D. SZÁZ, **Á. PERESZLÉNYI**, B. BERNÁTH, G. KRISKA (2019) Quantifying the polarised light pollution of an asphalt road: an ecological trap for the stonefly, *Perla abdominalis* (Guérin-Méneville, 1838) (Plecoptera: Perlidae). *Aquatic Insects* 40(3), pp. 257–269.
4. **Á. PERESZLÉNYI**, G. HORVÁTH, G. KRISKA (2017) ÉT-Etológia: A poláros fényszennyezés haszonélvezői. *Élet és Tudomány* 72(12), p. 604.
5. G. HORVÁTH, **Á. PERESZLÉNYI**, S. ÅKESSON, G. KRISKA (2019) Csíkos védelem a vérszívók ellen: bennszülöttek testfestésének áldásos parazitaellenes hatása. *Természet Világa* 150(9), pp. 390–396.
6. G. HORVÁTH, **Á. PERESZLÉNYI**, D. SZÁZ, A. BARTA, I. M. JÁNOSI, B. GERICS, S. ÅKESSON (2019) Zebracsíkok feltételezett hűtő hatásának kísérleti cáfolata (1. rész). *Fizikai Szemle* 69(4), pp. 117–121.
7. G. HORVÁTH, **Á. PERESZLÉNYI**, D. SZÁZ, A. BARTA, I. M. JÁNOSI, B. GERICS, S. ÅKESSON (2019) Zebracsíkok feltételezett hűtő hatásának kísérleti cáfolata (2. rész). *Fizikai Szemle* 69(5), pp. 147–154.