Final Report

Spectral measurement of phototactic responses and electroretinograms of arthropods, with special regard to the conservation of night-swarming mayflies and pest management (NKFIH-PD-131738)

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In the scope of the 3-year-long grant, 3 peer-reviewed D1 papers were published, and one is currently submitted. One Hungarian scientific paper and 3 popular science articles were also published, and 8 presentations were presented. I am grateful for the support of NKFIH.

Spectral sensitivity and the wavelength dependence of phototaxis of *Ephoron virgo*

Instead of the single planned publication, two papers were published about the vision of *E. virgo* mayflies [A1, A3].

In the first study [A1] we showed that attraction of *E. virgo* to light is increasing with decreasing wavelength, which means that UV and blue light is the most attractive. Hence, a spectrally optimized mayfly-protecting beacon should emit blue or cool white light, because *E. virgo* is mostly attracted to short-wavelength light. This was the reason for installing blue lights as a permanent beacon system on the bridge of Tahitótfalu (Northern Hungary). We also showed that long wavelength-dominated light sources with yellowish appearance for the human eye, for example, warm white LEDs or phosphor-converted amber (PC Amber) LEDs are the best choices for sites where *E. virgo* swarms are expected.

The second paper is about the visual ecology of *E. virgo*. As a result of electroretinography (ERG) recordings, we found that the eyes of larvae are mostly green sensitive, while the eyes of adults are primarily UV-sensitive. Larvae live in a dim, long wavelength-dominated environment, and the adults fly during the narrow time frame of the twilight, when the UV/green photon ratio of the global natural illumination (skylight) is maximal. Both life stages seem to have eyes adapted to the spectral characteristics of their natural visual environments [A3].

Two popular science articles were published about the above mentioned results [C1, C2] and three scientific [D3-5] and three popular science [D6-8] presentations were also presented.

Science has reviewed our research: https://www.science.org/content/article/can-scientists-help-insects-survive-their-fatal-attraction-light-night

Our results are summarized in a nice science documentary entitled "The Danube Mayfly Mystery/A dunavirág rejtély" made by György Kriska and Ferenc Kriska: https://www.youtube.com/watch?v=ep0M8Ypof-c&ab_channel=Gy%C3%B6rgyKriska. This movie will raise awareness for our research among people for a number of years.

Spectral sensitivity and the wavelength dependence of phototaxis of the fungus gnat *Lycoriella ingenua*

Experiments (behaviour + ERG recordings) were successfully performed. We found that the compound eyes of *L. ingenua* are mostly sensitive to UV-A and green light. Attraction to light was strongest in the green spectral region for very low light levels. On the other hand, for stimuli of higher light intensities, attraction was mostly elicited by UV light. Thus we revealed a strong light intensity dependence in the spectral sensitivity of phototaxis of this fungus gnat species. The paper was published [A2], the results were presented [D2], and a Hungarian paper was also published [B1].

As a continuation, I buit a trap prototype using the combination of UV and green LEDs. At the moment we are testing this trap with free-flying *L. ingenua* individuals.

Photo- and polarotaxis of black flies

In this topic we did not have luck. First, we had to find a new collection site, because probably due to water pollution, black flies have disappeared from Csömöri Creek. However, later in the neighbouring Mogyoródi Creek we found black flies. We collected pupae, let the dults emerge and we performed laboratory choice experiments with sticky polarized light stimuli in cages. On the one hand, the emerged adults died quite early. Secondly, we could not prove that polarotaxis is present in the collected black flies. Next, we went to the field to see if UV light is a key factor, because many aquatic insects detect polarization in the UV. Our carefully prepared equipment (sicky traps equipped with polarizers, white and black horizontal sticky surfaces, rainproof oil-filled polarizing traps) were completely destroyed and washed away by a flesh flood. Finally, the drought in the last year made insect collections more difficult. However, we could store some samples before the loss of the equipment, later it turned out, that the catched insects were not black flies. All in all, the balck fly topic was a great struggle and no reliable results came out neither from the lab nor from the field experiments.

Testing a high dynamic range LED light source in electroretinography

To demonstrate how to control simply the light intensity of LEDs in spectral sensitivity measurements without moving parts and neutral density filters, I successfully performed ERG measurements on mosquitos as model insects (*Culex* sp.). After evaluation of all data, I discovered that other researchers have very recently done it. So I modified my concept by trying to examine how the measured spectral sensitivity curve get distorted when eye stimulation is performed with light stimuli with different spectral bandwidths at different wavelengths. I also examined whether the measured spectral sensitivity curve can be undistorted if the bandwidth of the different stimulating LEDs are known. I found that significant distortion happen when the bandwidth of the stimuli gets greater than 30 nm. Since the bandwidth of most LEDs is narrower than this value, an ERG setup utilizing LEDs can produce acceptable results, however, the classical Xenon lamp + monochromator combination is better. The manuscript is still under preparation, because finally I concentrated on the not planned but much more important pest insect-related studies mentioned in the next two paragraphs (*Halyomorpha halys* and *Cacopsylla pruni*).

Spectral sensitivity of the brown marmorated stink bug, *Halyomorpha halys* (not planned but fits within scope)

Halyomorpha halys is a significant invasive agricultural pest. I measured the spectral sensitivity of its compound eyes with ERG. With chromatic adaptation I identified only two photoreceptors classes (UV and green), thus it seems that this species has a receptor set allowing only dichromatic vision. We also made behavioural phototaxis experiments, where we tested the spectral senstitivity of phototaxis. Generally, attraction of *H. halys* to light is increasing with decreasing wavelength, thus UV and blue light is the most attractive. The manuscript has been submitted to Pest Management Science on 12 Nov 2022 and it is still there. A popular science article was published [C3].

Colour vision of *Cacopsylla pruni* (not planned but fits within scope)

Colleagues from the Centre for Agricultural Research have brought me *Cacopsylla pruni* individuals, the eye spectral sensitivity of which I measured with ERG. *C. pruni* is an important pest insect of apricot, for example. With selective chromatic adaptation I revealed three different photoreceptor classes, which enabled us to model the colour vision of this insect species. Our results strongly suggest that during their dispersion in spring, besides olfaction, *C. pruni* individuals do use colour vision when seeking for blossoming apricot trees. The manuscript is currently under preparation.

Measuring the effectiveness of the mayfly-protecting beacon system at the bridge of Tahitótfalu (Northern Hungary) (not planned but fits within scope)

As a continuation of the mayfly protecting beacon's spectral optimization [A1], we started to measure the effectiveness of the mayfly-protecting beacon lights on the Tildy Zoltán Bridge in Tahitótfalu [A1, C2]. Photography and image processing enable us to quantify the proportion of saved mayflies during swarming at the bridge. Collection of much more data is needed, however, the preliminary data shows that approximately 85% of the arriving mayflies are kept above the river water, thus saved, becase after exhaustion they end up in the river with their eggs.

English peer-reviewed papers

[A1] Mészáros Á, Kriska G, **Egri Á** (2021) Spectral optimization of beacon lights for the protection of night-swarming mayflies. *Insect Conservation and Diversity* 14, 225–234.

http://real.mtak.hu/126992/

[A2] Kecskeméti S, Geösel A, Fail J, **Egri Á** (2021) In search of the spectral composition of an effective light trap for the mushroom pest *Lycoriella ingenua* (Diptera: Sciaridae). *Scientific Reports* 11, 12770.

http://real.mtak.hu/126961/

[A3] **Egri Á**, Mészáros Á, Kriska G (2022) Spectral sensitivity transition in the compound eyes of a twilight-swarming mayfly and its visual ecological implications. *Proceedings of the Royal Society B: Biological Sciences* 289, 20220318.

http://real.mtak.hu/141896/

[A4] **Egri Á.**, Mészáros Á, Kriska G, Fail J. (2022) Dichromacy in the brown marmorated stink bug? Spectral sensitivity of the compound eyes and phototaxis of *Halyomorpha halys*. *Journal of Pest Science* (**submitted**)

Hungarian scientific paper

[B1] Kecskeméti, S.; Fail, J.; Geösel, A.; **Egri, Á.** (2022) A *Lycoriella ingenua* optimális spektrumú fénycsapdájának nyomában. *Növényvédelem* 83 (4): 164–175

Hungarian popular science articles

[C1] Száz D, Kriska G, Farkas A, Horváth G, **Egri Á** (2020) Kérészvédő fénysorompó kialakítása a Dunán. *Elektrotechnika* 113: 38-39.

[C2] **Egri Á**, Mészáros Á, Farkas A, Kriska G (2021) A spektrumban rejlő lehetőségek: Színes fénysorompók a dunavirágért. *Élet és Tudomány* 76, 553–555.

[C3] Mészáros Á, Fail J, Kriska G, **Egri Á** (2022) Fénysorompó kártevőknek. *Természetbúvár* 77(2022/2), 17-19

Presentations

[D1] **Egri Á**, Farkas P, Fail J (2020) A dohánytripsz fajkomplex L2 típusának spektrális érzékenysége, Magyar Biofizikai Társaság Fotobiológiai Szekciójának miniszimpóziuma, 2020. december 18., 14:00-18:00, online Zoom meeting (Hungarian)

[D2] **Egri Á**, Kecskeméti S, Geösel A, Fail J (2021) Fénnyel a gombaszúnyogok ellen: a *Lycoriella ingenua* spektrális érzékenységének kísérleti vizsgálata, 67. Növényvédelmi Tudományos Napok, Budapest, 2021. február 16-17. (Hungarian)

[D3] **Egri Á**, Mészáros Á, Kriska G (2021) Beacon lights for the protection of night-swarming mayflies, 43rd international IAD conference, 9-11 June 2021, online Zoom meeting. (English)

[D4] Mészáros Á, Kriska G, **Egri Á** (2021) Kérészvédő fénysorompók optimális spektrumának meghatározása a védett dunavirág (*Ephoron virgo*), és más, este rajzó kérészek védelme érdekében, XV. Makroszkopikus Vízi Gerinctelenek Kutatási Konferencia, Agárd/Gödöllő, 2021. november 18-19., kivonatok gyűjteménye 33. o. (Hungarian)

[D5] **Egri Á**, Mészáros Á, Kriska G (2021) A dunavirág-védő fénysorompó optimális spektrumának nyomában, Magyar Biofizikai Társaság Fotobiológiai Szekciójának miniszimpóziuma, 2021. december 13., 14:00-18:00, online Zoom meeting (Hungarian)

[D6] **Egri Á** (2022) The scientific background of the film – The trapping effect of illuminated bridges on twilight-swarming mayflies, Academia Europaea Budapest Knowledge Hub – Danube Film Club, 10 March 2022, Hungarian Academy of Sciences. (English)

[D7] **Egri Á** (2022) Beacon lights for the protection of night-swarming mayflies, Conference of European Directors of Roads (CEDR) Webinar: Lighting and Light Pollution, 24 May 2022, online Zoom meeting. (English)

[D8] **Egri Á** (2022) Fénnyel az ökológiai fényszennyezés ellen, Gershoj Energia Gazdasági Konferencia, Tata, 2022. október 6. (Hungarian)