Safeguarding Insect Biodiversity by analyzing the sunlight they reflect

Insects are an incredibly important part of our ecosystem. They serve as pollinators for many of the fruits and vegetables that we eat. Due to climate change, the number of insects and the amount of insect species is declining at an alarmingly high rate, which can have catastrophic consequences for all other life on Earth. It is important to closely monitor this decline so that we can combat it effectively. However, it is difficult to find out how and where this decline is taking place. Current methods for insect monitoring rely on manual counting which is labor intensive. Automatic monitoring of insects could give better insight into this issue, which would allow us to combat it more effectively.

This thesis presents an automatic method to monitor insects by capturing and analyzing the spectrum of sunlight that is reflected by free-flying insects. This method is also referred to as Dark-Field Spectroscopy. A large advantage over manual counting of insects is that this does not harm the insects. Additionally, insects use sunlight to see each other. Therefore, these measurements can also provide clues about the mechanism behind how insects see each other. The research question that forms the basis of this thesis is whether the spectral analysis of the reflected sunlight contains extra information for identifying the species.

The experimental setup used to capture sunlight reflected by insects is shown in figure 1. Here, sunlight reflected by insects is captured by a large telescope that is placed in a field. A big black box is placed 100 meters away from the telescope. When there is nothing in the field of view of the telescope, it only sees the black box. When an insect flies through the field of view, it will reflect sunlight into the telescope. The light captured by the telescope is then sent into a spectral analyzer which can determine the different wavelengths reflected by the insect, which is also referred to as the spectrum. The spectrometer takes 20,000 measurements every second. The fastest wing beat belongs to mosquitoes, who beat their wings 1,000 times per second. This means that their spectrum is recorded 20 times during one wing beat.

During three days of recording in the field, 24.000 insects were observed flying through the field of view. The collected data is rich in information. The wing beat frequency is determined by light intensity fluctuations. Opaque wings exhibit thin-film interference, causing spectral fringes from which the wing thickness can be derived. The entire dataset is used to estimate the number of species through clustering, which means grouping similar observations to determine the number of species present.

The data clustering was done with and without the spectral information. Clustering with spectral information resulted in more groups compared to clustering without spectral information. The main conclusion of this project is that the spectral information helps to identify more species. Additionally, the data showed that sunlight reflected by insects has up to eight spectral components. This could be an explanation for why, for example, a dragonfly has five effective spectral bands.

Figure 1: Schematic of experimental setup used to catch sunlight reflected by free flying insects.