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Photonic Nanoarchitectures in Butterfly Scales Allowing Species Identification

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Abstract

We investigated photonic crystal colored blue butterfly wings with the use of optical spectroscopy. The extracted data from the optical spectra were analyzed by artificial neural network software. Over 100 exemplars of nine related *Polyommatus* species could be classified with 96% accuracy using only the spectral data measured in a nondestructive way.

Keywords: photonic crystals; butterfly wing scales; nanoarchitectures; artificial neural network; optical spectrometry

1. Introduction

Vision and color constitute a very important communication channel in the living world. Color is used for sexual communication, for warning potential predators, or for cryptic behavior [1]. Structural colors in the case of blue butterflies are arising from photonic crystal type structures.

In the present paper we investigated the photonic nanoarchitectures of nine Lycaenid butterfly species living in similar habitats with overlaps of their flying period. The dorsal side of the wings of these male butterflies has blue coloration of different hues. This blue sexual signaling color may constitute a clear enough discriminating signal for mate/competitor recognition. The analysis of the different blues, using an artificial neural network software (ANN), show that despite the fact that all examined species possess similar nanostructure, the spectral signatures exhibit enough characteristic differences which allow the unambiguous identification of conspecific individuals.

2. Experimental results and discussion

Due to the large number (110 pc.) of individuals used in the study, we developed a method which offers reproducible and characteristic spectra without the physical destruction of the specimens [2].

For an automated classification with ANN, a feature extraction is needed for every single spectrum. We defined parameters describing the characteristic shape of curves with discrete values that are used as inputs for the ANN. Half of all of the specimens were used for the teaching process of the ANN. After successful teaching we tested the network

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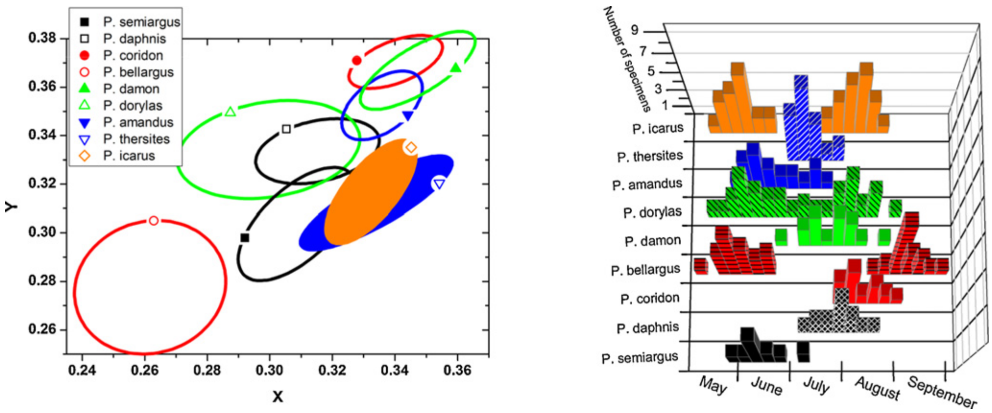

Fig. 1. (a) The measured colors placed in CIE 1931 xy chromaticity diagram; (b) Flying intervals diagram.

with the remaining samples, and we get 96% accuracy. This shows that the studied nine blue *Polyommatus* species have a characteristic hue [3].

Next, we compared the interval of time when the butterflies fly and their wing color. The spectra were first transformed into CIE XYZ tristimulus values, then the derived commonly used x and y values were represented in CIE 1931 color space chromaticity diagram. Each point in this diagram represents a specimen; the points assemble in domains (elliptical shapes in Fig. 1a). The determination of flying time intervals was based on museum collection data: we represented the exact time when the specimens were collected for each species (Fig. 1b).

On the CIE diagram we can find overlapped areas, for instance the ellipses for *P. icarus* and *thersites*. In the occurrence graph, *P. icarus* is shown in two separated generations while *P. thersites* fills up the gap between these two, which means these species are not flying in the same time. Therefore the mating of the butterflies is going to be successful: the further generations will inherit the proper genes [3].

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